
POST GRADUATE DIPLOMA ***IN*** ***SUPPLY CHAIN MANAGEMENT***

SEMESTER - II

WAREHOUSING & INVENTORY MANAGEMENT

Course Material

CONTENT DEVELOPED BY

V E Mohan

All rights reserved. No part of this work may be reproduced in any form, without the permission in writing from CII INSTITUTE OF LOGISTICS. Material adopted from the reading material prepared for the Post Graduate Diploma in Supply Chain Management, CII Institute of Logistics for the specific requirements of the course “PG Diploma in Logistics Management” offered for the Post Graduate students of MIM, Chennai. No part of this material could be shared by the intended readers with others.

Further information about the course offered by CII INSTITUTE OF LOGISTICS may be obtained from the CII INSTITUTE OF LOGISTICS (Southern Regional Headquarters) at Velacherry Main Road, Guindy, Chennai – 600 032.

For restricted circulation only.

INDEX

Chapter Number	TITLE	Page Number
1	Introduction to Warehousing Concepts, Decisions and Operations	5
2	Introduction to Inventory Management	53
3	Functions of Inventory	58
4	Methods of Controlling Stock Levels	79
5	Warehouse Management System(WMS)	87
6	Independent Demand Systems	99
7	Dependent Demand Systems	103
8	ABC Inventory Control	116
9	Multi-Echelon Inventory Systems	120
10	The Principles and Performance measures of Material Handling Systems	139
11	The Fundamentals of Various Types of Material Handling Equipment	147
12	AS/RS (Automated Storage & Retrieval System)	161
13	Bar Coding Technology & Application in Logistics Industry	171
14	RFID Technology & Applications	182
	PRACTICE AREA	206

INTRODUCTION TO WAREHOUSE CONCEPTS, DECISIONS AND OPERATIONS

Objectives

After studying this lesson, you will be able to:

- Explain the meaning of warehousing;
- Recognize the need for warehousing;
- Identify different types of warehouses;
- Explain the characteristics of ideal warehouses;
- Describe the functions of warehouses; and
- Enlist the advantages of warehouses.

1.1 Introduction

We need different types of goods in our day-to-day life. We may buy some of these items in bulk and store them in our house. Similarly, businessmen also need a variety of goods for their use. Some of them may not be available all the time. But, they need those items throughout the year without any break. Take the example of a sugar factory. It needs sugarcane as raw material for production of sugar. You know that sugarcane is produced during a particular period of the year. Since sugar production takes place throughout the year, there is a need to supply sugarcane continuously. But how is it possible? Here storage of sugarcane in sufficient quantity is required. Again, after production of sugar it requires some time for sale or distribution. Thus, the need for storage arises both for raw material as well as finished products. Storage involves proper arrangement for preserving goods from the time of their production or purchase till the actual use. When this storage is done on a large scale and in a specified manner it is called 'warehousing'. The place where goods are kept is called 'warehouse'. The person in-charge of warehouse is called 'warehouse-keeper'.

Warehousing refers to the activities involving storage of goods on a large-scale in a systematic and orderly manner and making them available conveniently when needed. In other words, warehousing means holding or preserving goods in huge quantities from the time of their purchase or production till their actual use or sale.

Warehousing is one of the important auxiliaries to trade. It creates time utility by bridging the time gap between production and consumption of goods.

The effective and efficient management of any organization requires that all its constituent elements operate effectively and efficiently as individual SBUs / facilities and together as an integrated whole corporate.

Across the supply chains, warehousing is an important element of activity in the distribution of goods, from raw materials and work in progress through to finished products. It is integral part to the supply chain network within which it operates and as such its roles and objectives should synchronize with the objectives of the supply chain. It is not a 'Stand-alone' element of activity and it must not be a weak link in the whole supply chain network.

Warehousing is costly in terms of human resources and of the facilities and equipments required, and its performance will affect directly on overall supply chain performance. Inadequate design or managing of warehouse systems will jeopardize the achievement of required customer service levels and the maintenance of stock integrity, and result in unnecessarily high costs.

The recent trends and pressures on supply chain / logistics-forever increasing customer service levels, inventory optimization, time compression and cost minimization –have inevitably changed the structure of supply chains and the location and working of warehouses within the supply chains network.

Certainly the old concept of warehouses as go downs to store goods has been outdated. Warehouses perhaps better referred to as distribution centers; exist primarily to facilitate the movement of materials to the end customer. There are exceptions such as Strategic stock-holding, but in all commercial applications; effective and more efficient movement of materials to the customer is the key, even if some inventory has to be held to achieve this.

Warehouses are built in all shapes and sizes, form facilities of a few thousand square meters handling modest throughputs, to-despite the previous comments-large capital-intensive installations with storage capacities in the 1,00,000- pallet-plus range, and very high-hundreds of pallets per hour –throughputs.

However, the concept of throughput rather than storage, and the pressure to optimize inventory with improved customer service level have also seen the development of distribution centers that do not hold stock-the 'stockless depot' –such as trans-shipment depots with more cross-docking operations.

Another issue that has exercised companies in recent days has been the degree of technology to utilize in warehousing operations. The choice spans from conventional warehousing –racking and shelving with fork-lift or even manual operations through to fully automated systems with conveyors and automated guided vehicles (AGVs) and from carousels to robotic applications. The reasons for the choice of a particular technology level are not always clear cut, and run the gamut of financial, marketing and other factors, from company's image or flexibility for future change through to personal perception of the appropriateness of a particular technology to a particular business or company.

Need for Warehousing

Warehousing is necessary due to the following reasons.

(i) Seasonal Production- You know that agricultural commodities are harvested during certain seasons, but their consumption or use takes place throughout the year.

Therefore, there is a need for proper storage or warehousing for these commodities, from where they can be supplied as and when required.

(ii) Seasonal Demand- There are certain goods, which are demanded seasonally, like woolen garments in winters or umbrellas in the rainy season. The production of these goods takes place throughout the year to meet the seasonal demand. So there is a need to store these goods in a warehouse to make them available at the time of need.

(iii) Large-scale Production - In case of manufactured goods, now-a-days production takes place to meet the existing as well as future demand of the products. Manufacturers also produce goods in huge quantity to enjoy the benefits of large-scale production, which is more economical. So the finished products, which are produced on a large scale, need to be stored properly till they are cleared by sales.

(iv) Quick Supply - Both industrial as well as agricultural goods are produced at some specific places but consumed throughout the country. Therefore, it is essential to stock these goods near the place of consumption, so that without making any delay these goods are made available to the consumers at the time of their need.

(V) Continuous Production- Continuous production of goods in factories requires adequate supply of raw materials. So there is a need to keep sufficient quantity of stock of raw material in the warehouse to ensure continuous production.

(vi) Price Stabilization- To maintain a reasonable level of the price of the goods in the market there is a need to keep sufficient stock in the warehouses. Scarcity in supply of goods may increase their price in the market. Again, excess production and supply may also lead to fall in prices of the product by maintaining a balance of supply of goods, warehousing leads to price stabilization.

Issues affecting Warehousing

Since warehouses, stores and distribution centers have to operate as essential component elements within supply chains net work, key decisions when setting up such facilities must be determined by the overall supply chain strategies for service and cost. The factors that should be considered include the following.

Market and product base stability

Long –term market potential for growth and for how the product range may expand will influence decisions on the size and location of a warehouse facility, including space for prospective expansion. These considerations will also impact on the perceived need for potential flexibility, which in turn can influence decisions on the type of warehouse and the level of technology to be used.

Type of materials to be handled:

Materials handled can include raw materials, WIP, OEM Auto spare parts, packaging materials and finished goods in a span of material types, sizes, weights, products lives and other characteristics. The units to be handled can range from individual small items through carton boxes, special storage containers for liquids, drums, sacks, and palletized loads. Special requirements for temperature and humidity may also have to be met in the case of perishables and all of these will impact on the type of warehouses and technology level.

Warehouse Facility: type, size and location.

The type of operation, the design capacity and size of a warehouse and its location will all be influenced if not directly determined by its exact role and position in the supply chain network, and the role, capacity and location of any other facilities in the supply chain. The customer base, level of inventory, the need for optimization of inventory, time compression in the supply chain and the overall customer service levels should also be considered when deciding on type, size and location. A further consideration here is whether the warehouse facility should be an own-account operation run by the company or outsourced and run by a 3PL.

Inventory and Inventory Location:

Within a supply chain network there is an issue not only of what materials to stock and in what quantities, but also in what locations .Options can include distribution centers devoted to specific markets or parts of the product range distribution centers dedicated to serving specific geographic areas, or regional distribution centers that hold for

example the fast moving product lines, with the slower lines held only in a Regional distribution centre (RDC). The option depends on such factors as customer base, product range and service levels required.

The options on the level of technology have already been noted, and the range can go from very basic installations with high manual input and least mechanization to fully automated and robotic installations.

The decision can be influenced by

- 1 Company-wide strategic marketing or employment policies,
- 2 Financial considerations,
- 3 Ability to achieve specified degree of throughput, and
- 4 Required customer service level.

Other factors can include the need for flexible operation to meet important demand fluctuations such as seasonal variations, and the perceived future stability and growth of the market and product range. The level of technology adopted in any particular application should be chosen because it almost nearly matches the given requirements and objectives. It is not true that automation or similar technologies are accurate in every case. It is true that good, probably computer-based, communication and information systems are vital in every application, irrespective of the technology level.

Choice of Unit load:

The option of unit load or loads – pallets, roll or cage pallets, tote bins - will be determined by the nature and characteristics of the materials passing through the supply chain, and this clearly encompasses an enormously wide range of goods, unit quantities, and pack types and sizes. This may appear as a very important factor more subject to basic operation than to strategic influences. However, within the warehouse it can influence the option of handling equipment and the types of storage systems. In the

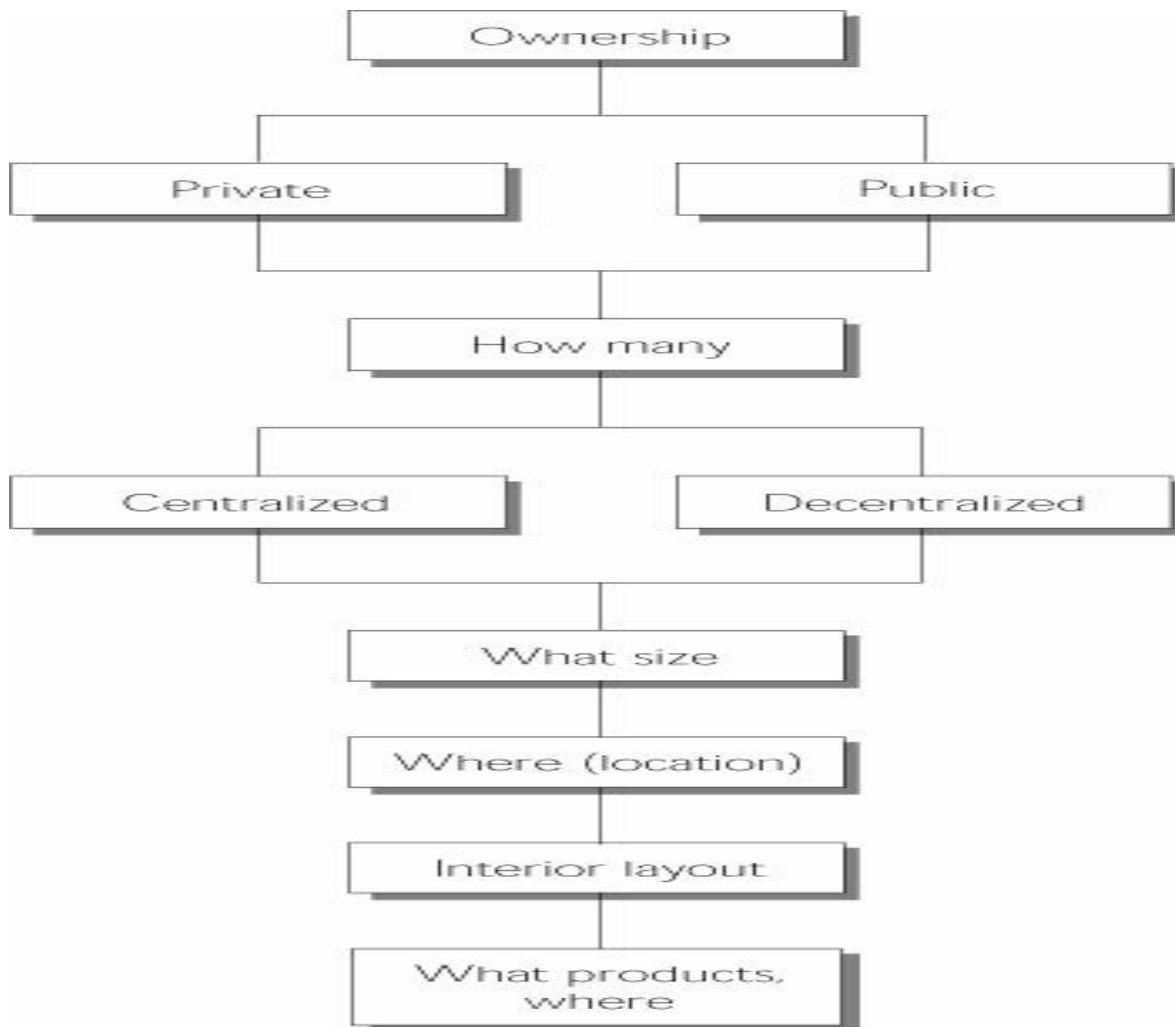
wider context it will affect transport operations in terms of vehicle loading and unloading and vehicle utilization.

Selection of warehouse

Warehouse Management and Physical Distribution are important flow control activities in the supply chain network. Regardless of the efficiency with which all preceding activities have been conducted, these activities have major influence in determining the degree to which total customer service level is achieved.

In present global business environment, the quality of warehousing and distribution management can have major impact on corporate performance and profitability.

The following flow chart clearly shows hierarchy of decisions to be made about the selection of warehouses in the strategic marketing policies with an objective of achieving max customer service level.

***Sequence of Warehousing Decisions***

The following points to be ascertained during the progression of making warehousing decisions.

- 1 Should warehousing be used?
- 2 What forms of warehousing should be used (public or private)?
- 3 What should be the size and number of warehouses utilized?
- 4 Where should warehouses be located?
- 5 What warehouse layout and design approach should be followed?

Types of Warehouses

After getting an idea about the need for warehousing, let us identify the different types of warehouses. In order to meet their requirement various types of warehouses came into existence, which may be classified as follows.

- i. Private Warehouses
- ii. Public Warehouses
- iii. Government Warehouses
- iv. Bonded Warehouses
- v. Co-operative Warehouses

i. **Private Warehouses** - The warehouses which are owned and managed by the manufacturers or traders to store, exclusively, their own stock of goods are known as private warehouses. Generally these warehouses are constructed by the farmers near their fields, by wholesalers and retailers near their business centres and by manufacturers near their factories. The design and the facilities provided therein are according to the nature of products to be stored.

ii. **Public Warehouses** - The warehouses which are run to store goods of the general public are known as public warehouses. Any one can store his goods in these warehouses on payment of rent. An individual, a partnership firm or a company may own these warehouses. To start such warehouses a license from the government is required. The government also regulates the functions and operations of these warehouses. Mostly these warehouses are used by manufacturers, wholesalers, exporters, importers, government agencies, etc.

iii. **Government Warehouses** - These warehouses are owned, managed and controlled by central or state governments or public corporations or local authorities. Both government and private enterprises may use these warehouses to store their goods.

Central Warehousing Corporation of India, State Warehousing Corporation and Food Corporation of India are examples of agencies maintaining government warehouses.

iv. Bonded Warehouses - These warehouses are owned, managed and controlled by government as well as private agencies. Private bonded warehouses have to obtain license from the government. Bonded warehouses are used to store imported goods for which import duty is yet to be paid. In case of imported goods the importers are not allowed to take away the goods from the ports till such duty is paid. These warehouses are generally owned by dock authorities and found near the ports.

v. Co-operative Warehouses - These warehouses are owned, managed and controlled by co-operative societies. They provide warehousing facilities at the most economical rates to the members of their society.

Private and public warehousing

A warehouse may be privately owned and operated by a company making its own merchandise. This is called a private warehouse. A warehouse may be owned and operated by another organization, including a government agency, and only used by a company on certain terms and conditions. This is called a public warehouse. A public warehouse may be owned by a company in the private sector but used by the general public. Irrespective of whether a warehouse is a private or a public warehouse, the following factors have to be taken into account to work out the cost of storage.

1. Interest on the capital used for buying the site.
2. Interest on the funds used to buy the furniture
3. Cost of repairs and maintenance
4. Depreciation on building and equipment
5. Insurance

6. If productivity (or efficient use) of the warehouse can be increased by 25 percent, there is an equivalent reduction in costs per unit handled and processed.
7. There are fixed costs in the shape of the cost of space per square meter or per cubic meter, etc.,
8. There are variable costs in the shape of cost per unit handled or processed, which must be added to the fixed costs.

Maximum efficiency is achieved by processing a larger number of units through the warehouse space. The larger the number of processed units the lesser the cost per unit. There are a few considerations which must be taken into account in the use of public and or private warehousing facilities. There are advantages and disadvantages on both, and the decision on establishing a private warehouse must only be made after a careful assessment of overall benefits.

1.3 Private warehousing

The construction and maintenance of private warehousing facilities can be extremely costly. All the expenses have to be carefully analyzed and evaluated.

These are

1. Fixed expenses incurred on the acquisition of land and building, normally which are very high
2. Expenses, incurred on ensuring that warehouses are properly equipped with Motorized Handling Equipment (MHEs) like fork lifts, conveyors, semi-automatic trucks, storage racks and bins, and mezzanine floors, etc.,
3. The cost of wages for staff required for peak activity periods like over time, which can be very high since retrenchment during slack periods may not be possible.

4. Extra payment like over time wage to be made for work on Saturdays, Sundays, and holidays.
5. Other service charges which are required in the maintenance of warehouse operations have to be taken into account.
6. Budgets have to be allocated for office and record keeping equipments for successful warehouse operations.
7. The cost of regular maintenance and repairs and the cost of such items as fire-extinguishers, fuel, air-conditioning, power and light have to be taken into account.
8. The cost of maintaining insurance records of premiums paid for fire, theft, and also for workmen's compensation.

1.4 Public warehousing

All the forgoing cost factors operate in public warehousing as well. But, in public warehousing, the expenses are distributed over several consignments of their clients. In most cases, therefore, the net result is a lower cost for each consignment. Warehousing has become a extremely specialized service and a public warehousemen can provide improved service with greater flexibility for the end user. A company running a private warehouse will have to evaluate the costs incurred with the total figure for the complete service through public warehousing.

Advantages of public warehousing

Some of the advantages of public warehousing are:

1. It is in general less expensive and more efficient and effective to achieve more customer service level.
2. Public warehouses are usually strategically positioned and easily available.
3. Public warehousing is adequately flexible to meet most space requirements, for several plans are available to suit the requirements of different users.

4. Fixed costs of a warehouse are distributed among many users. Therefore, the overall cost of warehousing per unit works out to a lower figure.
5. Public warehousing facilities can be given up as soon as necessary without any additional liability on the part of the user.
6. The costs of public warehousing can be easily and exactly ascertained, and the user pays only for the space and services he uses.
7. Conservation of capital is more in public warehousing
8. It has got enough space to handle peak requirements.
9. Public warehousing has reduced risk in their operations.
10. Public warehousing has got good economies of scale
11. It would give Tax advantages for end users.
12. Knowledge of exact storage and handling costs are available to end users.
13. It is insulated from labor disputes.

Disadvantages of public warehousing

1. problems in communication due to system incompatibility
2. Specialized services may not always be available whenever it is needed.
3. Adequate space may not always be available for end users.

Advantages of private warehousing

The advantages of private warehousing are:

1. Private warehousing offers better monitoring systems over the handling and storage of products as required by the management from time to time which would enhance the performance of the warehouse.

2. There is less likelihood or error in the case of private warehousing since the company's products are handled by its own employees who are able to identify the products of their own company.
3. If there is sufficient volume of goods to be warehoused, the cost of private warehousing comparatively less than that of public warehousing. The cost of private warehousing per unit may be actually higher if the private warehouse is packed to the brim.
4. Private warehousing is the best choice for some of the locations and the products handled because of the non-availability of the public warehousing.
5. Private warehousing has the opportunity to specially design its facilities for automatic material handling equipment where as public warehousing may have the same.
6. Enabling the end user to increase their efficiency by means of better design and structured lay-out.
7. efficient use of human resources in warehouse operation improves end users' overall performance
8. Intangible benefits in the form of cost reduction in all the warehouse operations.

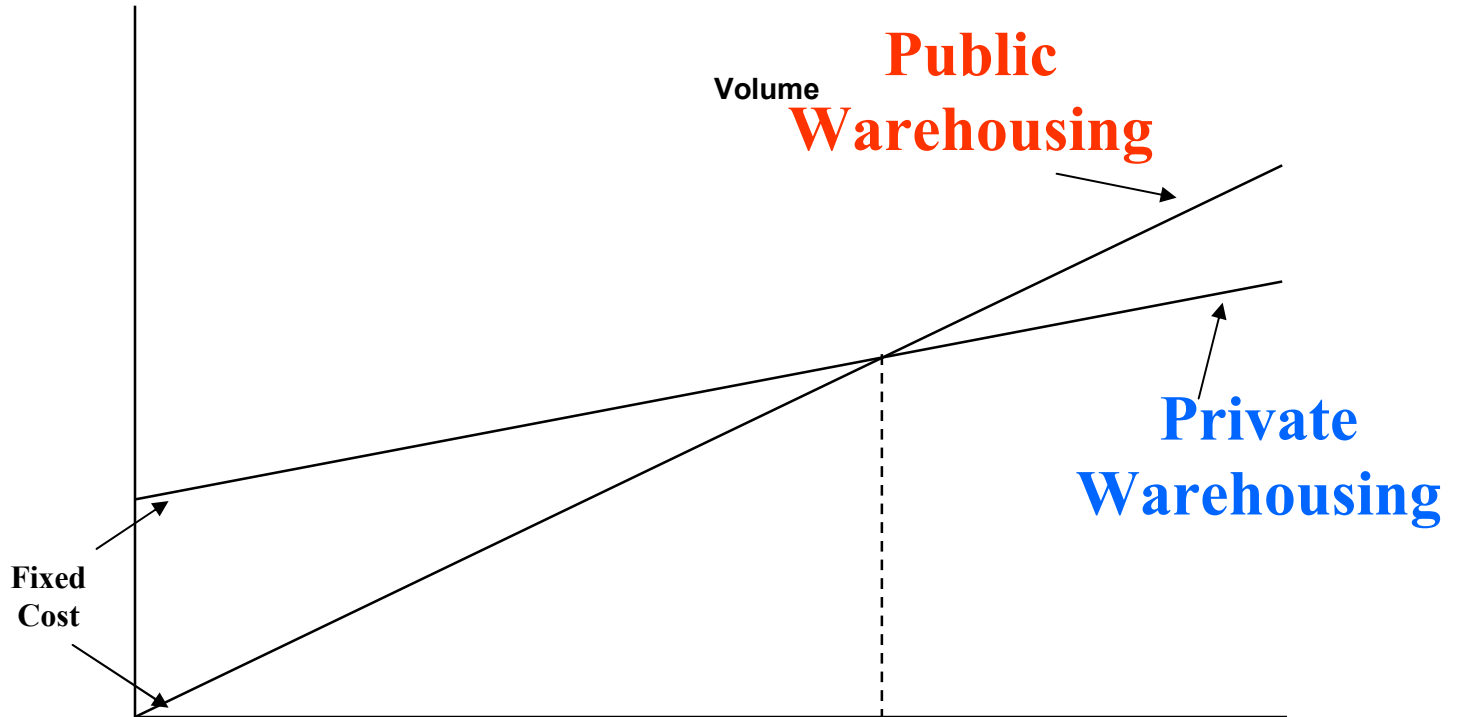
Disadvantages of private warehousing

1. Lack of Corporate flexibility which increases the complexity in the operation.
2. Financial issues
3. Low rate of return.
4. Tax issues are complicated.

The graph below clearly shows the impact of fixed costs with reference to volume of goods handled in public warehouse as well as in private warehouse. The organization has to take a strategic decision in the selection of type of warehouse which would suit its corporate goal. The organization has to ascertain the volume of goods to be handled in their business plan in order to decide on the type of warehouse.

Total

Cost



In practice, it is desirable to use both private and public warehousing according to the products and customer base. Also, private warehouses need not be owned. They may be rented or leased with or without material handling and other office equipments.

In a public warehouse, the warehouseman's integrity is the only security for the owner of the goods. A public warehouseman is responsible for the protection of the quality and quantity of the goods entrusted to him. He is not interested in the ownership or the use of goods, and is responsible for the goods only as a bailee. He is expected to take care of the goods as a man of normal prudence. He is an ideal third party between the buyer and the seller, between the borrower and the lender. A warehouse receipt for goods is accepted for sale or for borrowing. Thus, the warehouse renders physical support to trading.

Normally, goods in the go down of a trader or a private warehouse of a firm are a part of the general assets of the trader. They are not a separate entity. An additional Rs. 1, 00,000/- worth of goods might swell the inventory of the trader, but it does not

correspondingly increase his ability to borrow. If additional Rs. 1, 00,000/- worth of goods were stored in a warehouse, they can be used as collateral for borrowing. In the warehouse, the goods of one owner are segregated from those of other owners. The borrower has no control over these goods. They cannot be used, sold or even handled by the borrower without the previous and written permission of the bank. Thus, it becomes a perfect security for a loan. It is specifically insured beyond the reach of attachment or legal process.

There is less risk of fire in a warehouse than in a factory. Accordingly, insurance rates for goods in a warehouse are lower. Moreover, there is a practical guarantee against the temptation of a hard-pressed dealer or manufacturer to set fire to his establishment to convert the goods, which otherwise cannot be sold, into cash. In order to ensure that such an eventuality does not arise, organizations, like banks, insists that borrowers store

their goods in public warehouse. For this purpose, they offer concessional margins and rates of interest.

1.5 Location of warehouse

It is apparent that no seller can be equally near all customers or prospective customers. The space and time also impose significant limitation on the movement of goods from seller to buyer. In consequence, the location of the seller's production and distribution facilities in relation to those of customers is an important decision making process.

In this context, the location problem can be three types:

1. locating a warehousing system at the production facility itself;
2. locating a single central distribution warehousing system away from the production plant
3. Locating warehousing system at more than one place.

But for any type of problem, the optimal location is the one that is most likely to achieve the maximum rate of return on investment over the long run. For this optimal criterion, as a general rule, industrial companies tend to conform to one four locational orientations; raw materials, labour market, or power. Depending on the nature of production process, the types of materials required the characteristics of the end product and the tendency of buying companies to cluster in a given area, proximity to raw materials may be in overriding consideration. For other manufacturers, proximity to an adequate supply of labour or to customers may be the chief determinant of plants locations.

Even though the above considerations of raw material, labour, labour market or power have a primary influence on site selection, often more than one location would satisfy the primary need. This permits selection among the alternatives, the one that represents the most advantageous utilization of costs involved for providing the warehousing system while maintaining the desired quality of customer service. The total costs involved are made up of the cost of transporting all inputs required from their respective sources, the

cost of transporting outputs to the markets at the various locations and the cost of providing the warehousing facilities that have been or are to be acquired. The behavior of these considerations may be different and opposite with respect to location. Finding the least cost combination will require the trading off one castigatory of cost from another. That is, a higher transportation cost will have to be accepted to realize a proportionately greater reduction in storage systems. Thus choosing the most economical location and sizes for distribution warehouses is not a simple task. It may require the use of linear programming transportation technique, often supplemented with computer results.

In cases of warehouses stocking finished goods, factors such as proximity of ports, railway lines, quality of roads, availability of power etc., become important considerations. Added to all the above factors the warehouses should be constructed with sufficient flexibility for expansion needs.

The following considerations determine the location of a warehouse:

1. Market service area and cost of distribution from the warehouse to the market service area.
2. Satisfaction of transport requirements and facilities available in the form of rail, link roads and road vehicles.
3. Transportation rates prevailing in the area and distribution costs per unit.
4. Competition by rival companies and whether they have warehouse in the same area.
5. Availability of power, water, gas sewage disposal and their cost.
6. Labour supply and labour costs in the area.
7. Industrial relations climate and labour productivity.
8. Pricing arrangements and the level of service desired to be rendered in terms of availability of the product to the customer.

9. Individual company requirements and constraints.
10. Real estate, excise and government taxes assessed in the area.
11. Attitudes of local residents and government towards establishment of the warehouse.
12. Restrictions associated with warehouses.
13. Potential for later expansion.
14. Cost of land for the warehouse and other costs.
15. Possibility of change in the use of the facility at a later date if the company so desires, and lease or sale of the land and buildings.

Characteristics of Ideal Warehouses:

- I. Warehouse should be located at a convenient place near highways, railway stations, airports and seaports where goods can be loaded and unloaded easily.
- II. Mechanical appliances should be there to loading and unloading the goods. This reduces the wastages in handling and also minimises handling costs.
- III. Adequate space should be available inside the building to keep the goods in proper order.
- IV. Ware houses meant for preservation of perishable items like fruits, vegetables, eggs and butter etc. should have cold storage facilities.
- V. Proper arrangement should be there to protect the goods from sunlight, rain, wind, dust, moisture and pests.
- VI. Sufficient parking space should be there inside the premises to facilitate easy and quick loading and unloading of goods.
- VII. Round the clock security arrangement should be there to avoid theft of goods.
- VIII. The building should be fitted with latest fire-fighting equipments to avoid loss of goods due to fire.

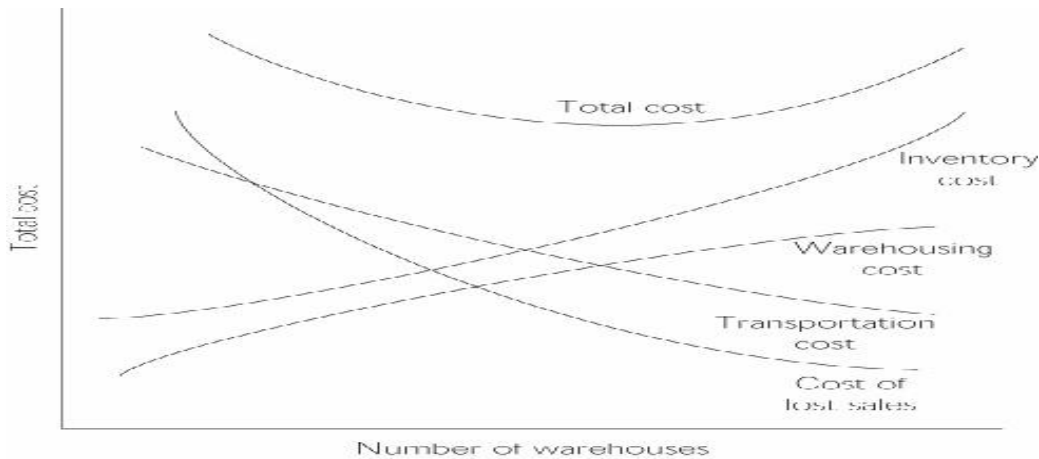
Qualitative factor rating method of comparison

Factor rating is a means of assigning quantitative values to all the factors related to each decision alternative and driving a composite score that can be used for comparison. It allows the decision maker to inject his own preferences into a location decision and it can accommodate both quantitative and qualitative factors.

Procedure for qualitative factor rating

1. Develop a list of relevant factors.
2. Assign a weight to each factor to indicate its relative importance (weights may total 10)
3. Assign a common scale to each factor (ex 0-100 points) and designate any minimum.
4. Score each potential location according to the designated scale, and multiply the scores by the weights.
5. Total the points for each location, and choose the location with the maximum points.

Weighted scores are computed by multiplying the score times with the assigned weight and summing those products. Based on this data, a location among many would get selected as the preferred location for the new warehouse.



Factors Affecting the Number of Warehouses

- Inventory costs
- Warehousing costs
- Transportation costs
- Cost of lost sales
- Maintenance of customer service levels
- Service small quantity buyers

1.6 Functions of the Warehouse

1. **Receiving**-This includes the physical unloading of incoming transport, checking, recording of receipts, and deciding where the received goods are to be put away in the warehouse. It can also include such activities as unpacking and repackaging, quality control checks and temporary quarantine storage for goods awaiting clearance by quality control
2. **Inspection**- Quality and quantity check of the incoming goods for their required characteristics

3. **Repackaging**- Incoming lot may be having non-standard packaging which may not be stored as it is in the respective location. In those cases these materials have to be pre packed in unit loads/pallet loads suitable for storage.
4. **Put away** – Binning and storing the goods in their respective locations including the temp locations from the receiving docking area.
5. **Storage** – Binning the approved material in their respective locations.
6. **Order-Order picking / selection** –Goods are selected from order picking stock in the required quantities and at the required time to meet customer orders. Picking often involves break bulk operations, when goods are received from suppliers in, say, whole pallet quantities, but ordered by customers in less than pallet quantity .order picking is important for achieving high levels of customer service; it traditionally also takes a high proportion of the total warehouse staff complement and is expensive. The good design and management of picking systems and operations are consequently vital to effective warehouse performance
7. **Sortation** – This enable goods coming into a warehouse to be sorted into specific customer orders immediately on arrival. The goods then go directly to order collation.
8. **Packing and shipping** – Picked goods as per the customer order are consolidated and packed according to customer order requirement. It is shipped according to customer orders and respective destinations.
9. **Cross-docking** –Move products directly from receiving to the shipping dock – these products are not at all stored in the specific locations.
10. **Replenishing** – This is the movement of goods in larger order quantities, for example a whole pallet at a time , from reserve storage to order picking, to ensure that order picking locations do not become empty. Maintaining stock availability for order picking is important for achieving high levels of order fill.

1.7 Activity Profiling

Warehouse activity is primarily divided into two activities

- ✓ Item activity profile
- ✓ Order activity profile

Order activity profile includes

- Order mix distribution
- Lines per order distribution
- Cube per order distribution.
- Lines and cube per order distribution.

Order Mix distribution

Variety of order mix distributions that are helpful for plotting warehouse operating strategy. Three are considered the most helpful are the **family mix distribution, the handling unit distribution and the order increment distribution.**

Family Mix Distribution

In many cases, operating strategy of the warehouse is dictated by the order mix-the extent to which orders require items from multiple families of items. If the orders are pure, means only one of the item, then it is early indicator that zoning the warehouse will create a small warehouse within the warehouse will ensure the goods productivity and customer service.

Example of family Mix Distribution

Items A which carry more volume and weight has to be considered as Flat Stock, Item B Which is less volume and weight than the Item A named as cut stock, Item C which is less volume and weight than the Item B named as envelope.

Example

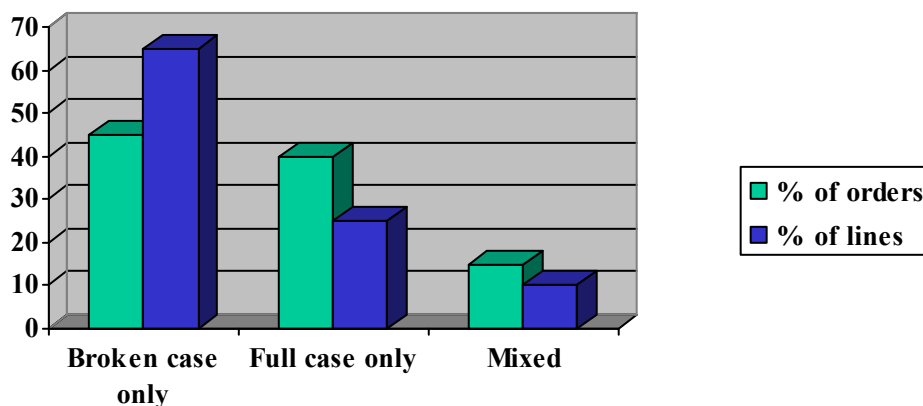
- **Rice Bags** - **Flat Stock**
- **Milk powder Tin** - **Cut Stock**
- **Tissues** - **Envelope.**

Assign the materials in warehouse or retail outlet; zone the warehouse by these three item families. If the customer orders are mixed then in pallet building, we would start with flat stock, the cut stock and put the envelope stock on top of that. If that is this way we will have to travel across those zones or pass a pallet from one zone to the next.

Zoning the warehouse by item family will yield good productivity, customer service, and increase storage density performance.

Full/Partial pallet Mix Distribution

With the full-partial mix distribution, try to determine if we need separate areas for pallet picking and case picking. In some warehouses, pallet and case picking are performed out of the same item location, aisle, and /or area of the warehouse. In general, it is good idea to establish separate areas for pallet and case picking-replenishing a case picking/line area from a pallet reserve/picking area. This distribution simply helps reinforce the point and helps to identify warehouse within a warehouse opportunities.



(Source: Edward Frazelle, World class warehousing)

In this figure 50 percent of the orders are completable from partial pallet quantities, that is, just case picks; 40 percent of the orders are fillable from full pallet quantities, and the remaining 20 percent 10 percent of the orders require both the partial and full pallet quantities.

Should we consider a separate case picking and pallet picking area? If we did, would we pay a big Penalty for mixed orders that require merging of the partial and full pallet portions of the order? No, we really wont .That only happens 20 percent of the time. For 80 percent of the orders, zoning based on pallet or case picking creates a warehouse within a warehouse. Warehouse management system should help by classifying them immediately as a pallet pick order, a carton pick order, or a mixed order.

Full/Broken Case Mix Distribution

In some of the organization full and broken case picking are performed in the same item location, where there is lot of mixing of products in various zones. In general, it is good option to perform in a separate area for full and broken case picking.

This type of distribution helps to reinforce the point and helps to identify warehouse within a warehouse opportunities. Once the customer order reaches the warehouse management system, it should classify them immediately as pallet pick order, carton pick order or a mix order.FMCG business services most of the orders as mix order distribution, since the products are assigned as full pallet and broken cases separately, it is easy to pick the materials against the mixed customer orders.

Order Increment Distributions

With the order increment distribution, we determine the portion of unit load requested on a customer order. Assume there are 100 cartons in a pallet and the customer orders

only 50 cartons. In that case, he ordered 50% of the pallet. In some cases customer will order only 20% of the pallet, this is an unusual distribution.

Suppose there are 100 cartons on a pallet and a customer orders 100 cartons, it is feasible to give the whole pallet which is holding the full quantity of 100 cartons, instead of picking from different locations. This type of operation is not only good practice for us, it will also help customers to receive as full lot.

In this case a decision can be taken to design the unit loads based on the pallet size. We should build some quarter and half-pallet unit loads. So when ever the customer places an order for a quarter pallets we have the unit load preconfigured.

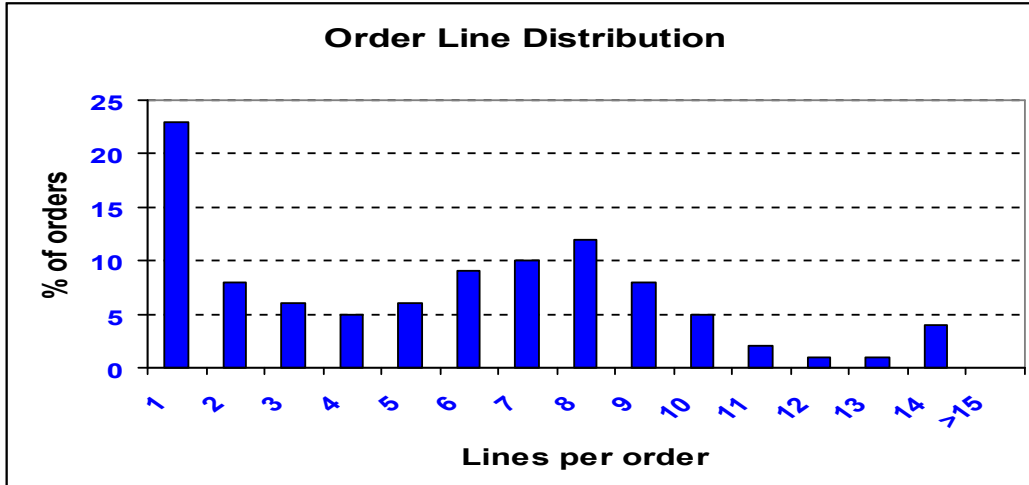
In case of manufacturing industry, the palletizer that sits on the border and all we have to do is set the palletizer to put a pallet in place about four times as often to build quarter pallets and twice as often to build half pallets. If it is distribution center, pallets can be designed based on the unit loads as a value added activity in distribution center.

So that we encourage people to order in quarter and half pallet the pattern of ordering the preconfigured loads. We can further encourage the practice of ordering price discounts designed around efficient handling increments.

As a result, we would like to set price breaks at a half carton and at a full carton to encourage customers who are almost ordering that quantity now to order in full carton increments.

Lines Per order distribution

In this we can see line per each and every customer orders.



(Source: Edward Frazelle, World class warehousing)

The above graph clearly says 50% percent of the orders are single line items, 7% is 2 line orders, and 10 % are the 7 to 8 line orders. Justify and see where the pressure is? It's in single line orders.

Now we need to consider the operating strategies for this type of order profile.

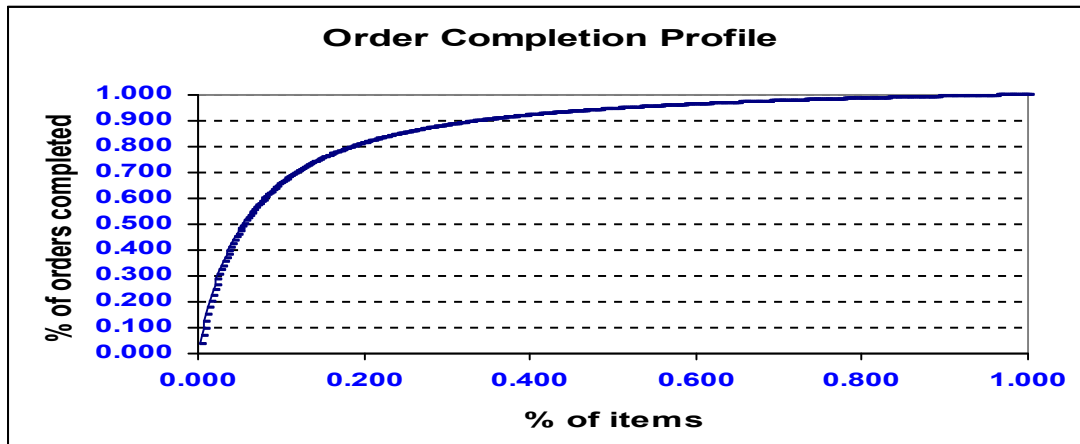
Mostly single line orders are back orders and emergency orders. Excellent opportunity for back orders is cross docking and also these types of orders can be batched together for single line picking tours and printing single line orders in location sequence.

Item Activity Profile:

Primarily item activity profile is used to allocate each item in the warehouse.

- ✓ Storage mode
- ✓ Space to allocate for each item category.
- ✓ Where the items are to be stored.

The item activity profile includes the following activity distributions.

Item Popularity Distribution:

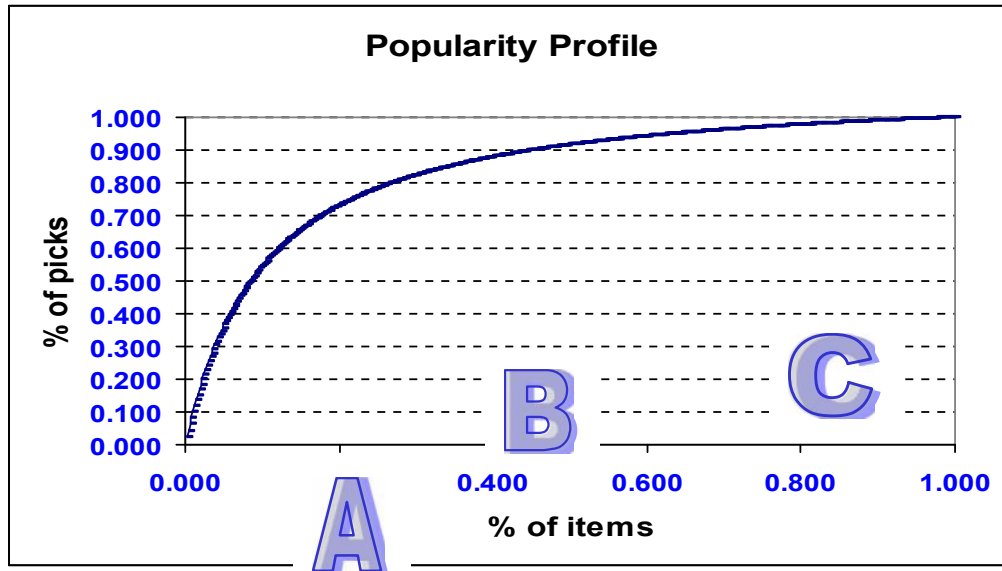
(Source: Edward Frazelle, World class warehousing)

The popularity distribution sometimes called as ABC curve represents that x percent of the curve associated with y percent of the SKUs (ranked by descending popularity).

The above graph illustrate that 10 percent most popular items represent 70 percent of the picking activity, the 50 percent most popular items represent 90 percent of the picking activity and so on.

For example the top 5 percent of the items (Family A) may make up 50 percent of the picking activity, the next 15 percent of the items (Family B) may take us to 80 of the picking activity and remaining 80 percent of the picking activity, and the remaining 80 percent of the picking activity (Family C) cover the other remaining picking activity.

or these families we can assign the different type of storage methods



(Source: Edward Frazelle, World class warehousing)

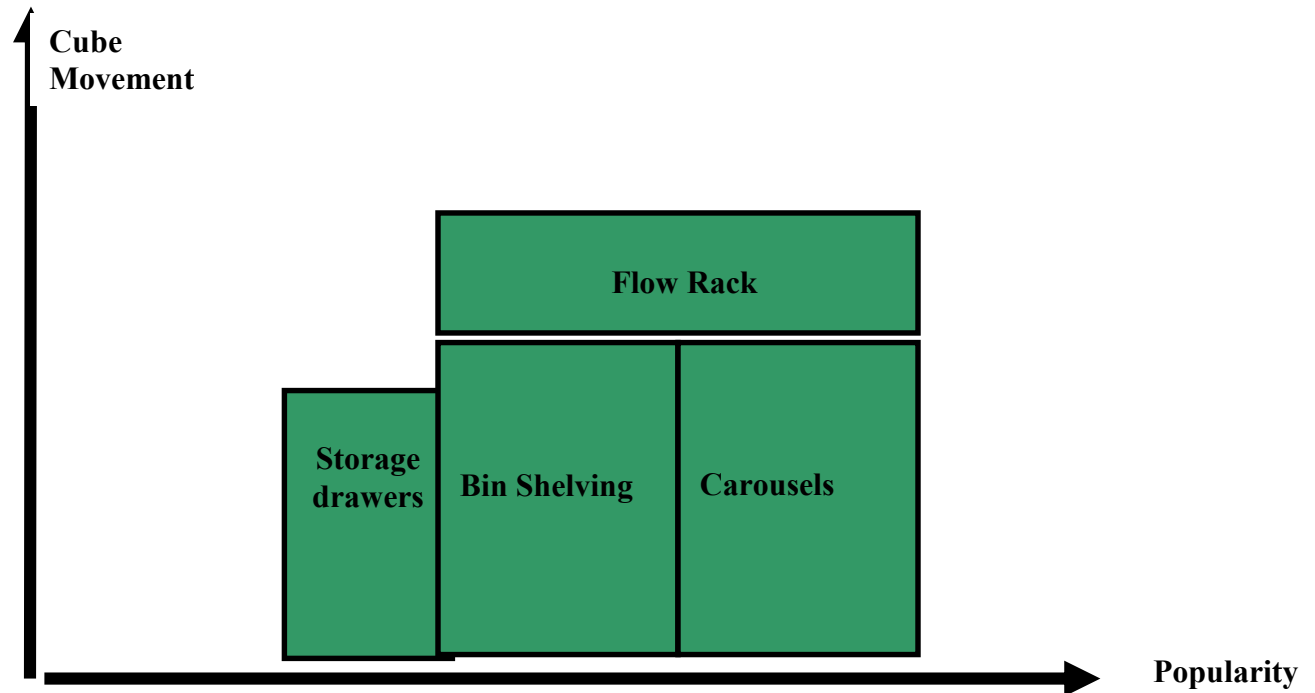
Decisions on the storage of ABC classified items:

A family item is to be stored in automated highly storage mode, **Family B** in a semi – automated moderately productive picking mode and **family C** in a manual picking mode that offers high storage density.

The basic principle is to assign the most popular items to the easy accessible area, in order to optimize the traveling time and to increase the picking efficiency.

Popularity – Cube Movement Distribution

Done properly, slotting takes into account both the item-popularity distribution and the cube-movement distribution. These distributions can be combined into a joint distribution. An example popularity –cube-movement distribution for broken case picking is presented



(Source: Edward Frazelle, World class warehousing)

In this example, those item exceeding a certain cube-movement threshold are assigned to carton flow rack, Materials with high cube and turn over frequently, need to be restocked at frequent basis. It also needs a larger storage area with to relocate or restock the items, when compare to the materials with low cube movement. Hence this type of materials is to be stored in large storage area along the pick line-carton flow rack.

Materials with low cube movement, and high popularity are generating many picks per unit of space that they occupy and do not occupy much space along the pick line. This need to be in highly productive picking mode. In this case light directed carousels are recommended because the picking productivity is high and we can afford the carousels for items that do not need large storage housings on the pick line and do not need to be restocked frequently.

Items with low popularity and low cube movement cannot be justifiably housed in an expensive storage mode. Hence they are candidates for bin shelving and modular drawers. Once the storage mode assignments have been made, the preference regions for each storage mode become their popularity-cube movement distributions. Those items in the bottom right-hand portion of the distribution generate the most picking activity per unit space they occupy in the storage mode. Hence, they should be assigned to golden zones. Those items in the upper right hand and lower left hand generate a moderate number of picks per unit of space they should occupy in the storage mode. Hence, they should be assigned to silver zones.

Finally, those items in the upper left hand quadrant of the distribution generate the fewest picks per unit space they occupy and they should be assigned positions in the bronze zone.

This example is not meant to make an end-all recommendation for slotting broken case picking systems. That depends on many other factors, including the wage rate, the cost of space, the cost of capital, the planning horizon, and so on. Instead, this example is presented to illustrate how the popularity-cube-movement distribution is used in the slotting process. Once in place, the distribution provides most of the insights required for slotting the entire warehouse.

Item-Order Completion Distribution

The item-order completion distribution identifies small groups of items that can fill large groups of orders. Those small groups of items can often be assigned to small order completion zones in which the productivity, processing rate, and processing quality are two to five times better than that found in the general warehouse.

The item-order completion distribution is constructed by ranking the items from most to least popular. Beginning with the most popular item, then the two most popular items,

then the three most popular items, and so on, the items are put against the order set to determine what portion of the orders a given subset of the items can complete.

1.8 Warehouse Operations –Centralized and De-Centralized

In a multiple warehouse, the warehousing operations can either be centralized or decentralized. In decentralized warehousing operations, each warehouse is considered as a separate entity. Thus each warehouse will have a separate safety stock, there will be orders from lower warehouse to the upper warehouse and there will be in-transit stocks. Each warehouse will optimize inventory individually. This type of decentralizing will be advantageous for the following situations.

Consumption centers are located at different places and at distant places. The transaction of goods is very high. The advantages of such system are

- This prevents obsolescence and also prevents accumulation of surplus materials and
- This offers service where it is needed.

But the system has the disadvantages of having high running cost due to increased stock and personnel in each warehouse and due to handling of more information.

As against this, in a centralized system of warehousing operations, order processing, storing of safety stocks and control stock movements will be done centrally by a central warehouse. The important requirement for this centralized system is a well established information system. But this system has the following advantages:

- 1) Orders for multiple items on a single source can be bunched together.
- 2) There will be reduction in safety stock by a factor equal to n where n is the number of warehouses.
- 3) Similarly total inventory cost is also reduced by a factor equal to n .

These reduction in inventory costs adequately justify the cost of information system .In such a centralized system, the central warehouse will have to do the additional record keeping and decision making required in a branch warehouse operation. That is, it should keep track of each branch's current stock of each item, its rate of sale at each branch, the amount currently on order and amount in transit. The central warehouse, with these above information's will have to make decisions about when and how much to reorder from the factory. If the decisions are made on the basis of outdate, incomplete and erroneous information, many of the decisions will late turn out to be wrong, a consequence that will raise costs and reduce sales.

1.9 Storage systems

The type of materials passing through warehouses varies enormously, with different sizes, weights, shapes, levels of fragility and hazard characteristics. A major benefit of unit loads such as pallets is that they enable the use of standard storage systems and handling equipment, irrespective of what is handled. Nevertheless variations in throughput and order picking patterns make it appropriate to have different types of storage system, with different operational characteristics, so that systems can be selected that most closely match the needs of the wider system within which they are to operate.

The key factors influencing the choice of a storage system are:

- The nature and characteristics of the goods and unit loads held;
- The effective utilization of building volume-horizontal and vertical:
- Good access to stock;
- Compatibility with information system requirements;
- Maintenance of stock condition and integrity;
- Personal safety;
- Overall system cost;

When comparing the costs of different storage systems, it is not only the storage equipment cost that should be taken into account. Other cost elements that could be affected by the choice of system include:

- Space-land, building and building services;
- Fire protection;
- Handling equipment including maintenance;
- Staff;
- Information management systems.

One way of classifying storage systems could be:

- Bulk storage for solids, such as silos, bunkers and stockpiles;
- Loose item storage, ex casting and fabrications held loose on the floor;
- Pallet storage systems;
- Small item storage for individual items or small unit loads;
- Non-standard unit loads such as long loads.

The location of stock within a store is an important aspect of stock management and can be considered at different levels of detail. For ex, the overall positioning of stock within particular areas of the warehouse can influence the total amount of movement required to get material into and out of stock. It can also affect the efficiency with which order picking operations can be carried out by affecting the distance order pickers have to travel to get to required stock.

Fixed and random stock location

The effective storage capacity of a given installation is influenced by whether individual product lines are held in fixed and dedicated locations, or whether any product line can be located randomly in any available storage location.

If a fixed location system is used, any specific location can be used for its designed product line, and never for any other product. Consequently the installation must be designed with enough capacity to hold the maximum stock of every product line.

With random location, when any empty location can be utilized for any product line as required, the size of installation can be reduced, since the probability of every product being in stock at maximum stock level at the same time is virtually nil. In this case, the required storage capacity can be calculated from the sum of the average stock levels for all product lines, inflated by a factor, say 10%, to account for fluctuations about the average.

Random location is often used for reserve storage, which tends to take up the largest area in a warehouse, and fixed location for order picking stock, which enables the use of concepts such as popularity storage- fast-moving product lines located to minimize picker movement.

Palletized storage systems

Block staking

Block storage does not use any storage equipment. Loaded pallets are placed directly on the floor and built up in stacks, one pallet on top of another to a maximum stable height. The pallet loads must be capable of carrying the superimposed pallets, and the top of each load should be flat enough to provide a stable base for the next pallet.

Block stacking is suitable for that part of the product range where there are few product lines, each with high stock level, and where very strict FIFO movement of stock is not required. The advantages are good use of area, flexibility to change the layout of the blocks and quick to stock for rapid throughput.

Drive-in and drive-through racking

Although this is a racked storage system, it is operationally similar to block storage. There should only be one product line in each row, and the effective utilization of the pallet positions is about 70%. The racking structure supports the weight of the pallets so this system is suitable for high stock product lines, where strict FIFO movement is not required, but where the pallet loads are not strong enough or of regular enough shape to carry superimposed loads. This system consists of vertical support frames, tied at the top, with cantilever pallet support beams at different heights.

Push back Racking

This type of racking is a comparatively recent development. Like drive-in racking it gives high-density storage and can be built to any height up to the maximum lift height of the lift trucks accessing it. Pallets can be stored up to about four deep in the racking, on either side of the access aisle. The basic operational difference between this system and block stacking or drive-in racking is the increased selectivity achieved. There should be no mix of product lines in any one lane, but there can be between the lanes in any row.

Adjustable Pallet Racking-(APR)

Adjustable pallet racking is probably the most widely used type of pallet racking, and offers free access to every pallet held. It can be built to match the lift height of any fork-lift truck. Unit loads other than pallets can be stored using APR, and there is a range of accessories such as drum supports and channel supports for post pallets to facilitate this.

The conventional way of laying out APR is to have one row single deep at each end of the installation, with back-to-back rows in between. This gives every truck aisle access to two rows of racking, and minimizes the number of aisles required.

APR is a flexible, versatile storage system, which gives excellent stock access. It is simple in concept, easily laid out, and damaged parts are easily replaced. It can be suitable for fast-moving and slow –moving stock, and for product lines with high or low levels of palletized stock-holding. However, APR does not make good use of volume of building volume.

Double deep Racking

If some loss of totally free access to stock can be accepted, although not nearly as severe as in block, drive-in or push back storage, space utilization can be improved using double deep racking. This supports pallets on pairs of beams as in APR, but improves space utilization by eliminating alternate access aisles, and using a double reach fork-lift truck, which can access not just one but two pallets deep into the racking.

Powered Mobile racking

Powered mobile racking is effectively single deep APR, with the racking, except the end or outer rows, mounted on electrically powered base frames. Operationally it has similar characteristics to APR, but it is slower in use, and the pallet position utilization is likely to be similar to APR at 90 to 95%. This type of storage is expensive in equipment and floor costs, and it tends to be slow in operation. However it gives very dense storage, and is suitable for the typically large number of product lines forming the 'Pareto tail' of a product range, where individual product lines have low stock and low throughput. It also finds use in cold-storage applications where space costs are especially high, and however temperature variations are reduced by cutting the air space in the storage area.

Pallet live storage

Live storage systems are made up of inclined gravity roll conveyors, laid out side by side and at a number of vertical levels. Pallets are fed in at the higher end and removed as required at the lower. Such a system imposes FIFO. The only accessible pallets are at the out feed end, so any one lane should only hold pallets of the same product line.

Pallet live storage systems are suitable for very fast-moving product lines. They can provide effective order picking regimes, which automatically refill empty locations, and also provide physical separation between picking and replenishment operations.

Small item storage systems

As with palletized storage systems, there is a range of different types system for holding small items. With small item storage it often happens that different systems are incorporated into one installation. For ex, drawer units and cabinets may be built into a shelving installation. Consequently the concept of standard equipment sizes and modularity is important for small item storage systems.

The following lists are some of the storage systems used for small items:

- Shelving
- Tote bins
- Drawer units

- Dynamic systems –mobile and live storage
- Mechanized systems- carousels and mini loads

1.10 Summary

Warehouses may be distributed in the field in order to shorten transportation distances to permit rapid response to customer demand. This study material shows us the process of decision making in the selection of type of warehouse between private and public warehouse and its locational preferences in the whole supply chain network.

It gives various functions involved in warehouse operations. It also gives the selection of storage systems required to suit various types of goods in order to increase the efficiency of warehouse operations.

Qualitative factor rating method is helpful in the selection of the location of a warehouse and activity profiling is useful for the design of storage systems and material handling equipments

1.11 Key words

Trade off	Logistics	Warehouse
Optimize	Supply chain network	Flexibility
Distribution	AGV (automated guided vehicles)	Inventory
Synchronize		Facility
Equipments	Pallets	
Technology	MHE (material handling equipment)	Centralized
Automated		De-centralized
Handling	Put away	Bulk storage
Flow	Cross-docking	Racking
Control	Order picking	
Performance	Sortation	
Storage Cost	Replenishing	
	Activity profiling	

1.12 Self-assessment Questions

1. Maintaining stock availability for order picking is named as
 - a. Order picking
 - b. Sortation
 - c. Receiving
 - d. Replenishment

2. RDC refers to
 - a. Reliable dispatch center
 - b. Return dispatch center
 - c. Regional distribution center
 - d. Random distribution center

3. Good access to stock is one of the key factors
 - a. Influencing the choice of a storage system
 - b. For designing a warehouse
 - c. For designing a material handling equipment
 - d. For designing a production system

4. Carousel storage system is used
 - a. To increase the operator movement when accessing stock
 - b. To minimize the movement of Material handling equipments
 - c. To minimize the operator movement when accessing stock.
 - d. To minimize the stock movement

5. Collation, which is one of the functions of a warehouse, relates to
 - a. Receiving the goods

- b. Dispatching the goods
- c. Storing the goods
- d. Bringing and consolidating the goods before dispatch

6. Block Stocking

- a. Uses the racking storage systems
- b. Uses vertical Carousel storage systems
- c. Does not use any storage systems
- d. Uses horizontal storage systems

7. The most common measure of picking performance is

- a. Fill rate
- b. Perfect order fill rate
- c. Pick rate
- d. Binning rate

8. Efficiency in order picking has an immediate impact on

- a. Inventory reduction
- b. Customer service level
- c. Material handling equipments
- d. Storage systems

9. Aisle space is considered for

- a. Selection of material handling equipment
- b. Designing a warehouse layout
- c. Designing a product
- d. Designing a storage system

10. Carousel is a good storage system for storing

- a. High volume items
- b. Heavy weight items
- c. Small items
- d. Liquids

11. Choice of unit load is determined by

- a. By the type of material handling equipment
- b. By the size and design of warehouse
- c. By the nature and characteristics of goods passing along the supply chain
- d. By the type of storage system

12. Benefit of unit load is

- a. To control the inventory in a warehouse
- b. To enable the use of standard equipment irrespective of the products being handled
- c. To reduce the fatigue of the operator
- d. To increase the through –put velocity

13. Unit load storage is

- a. Is pallet storage
- b. Loose item storage
- c. Bulk storage
- d. Small item storage

14. Stock location affects

- a. The inventory
- b. The efficiency of material handling system
- c. The efficiency of overall warehouse operation
- d. The product quality

15. Random location is used for

- a. Reserve storage
- b. Popularity storage
- c. Liquid storage
- d. Bulk storage

16. Most widely used pallet racking is

- a. Push back racking
- b. Adjustable pallet racking
- c. Double deep racking
- d. Powered mobile racking

17. Cantilever racking are used to store

- a. Long rigid bars and tubes
- b. Small items
- c. Liquids
- d. Cartons

18. One of the key factors influencing the choice of storage systems is

- a. Inventory policy
- b. Geographical location of the warehouse
- c. Material handling equipment
- d. The nature and characteristics of the goods and unit loads held

19. Mechanized sortation systems use a

- a. Continuous loop conveyor moving between off-take chutes
- b. Pallet tacking
- c. Robot

- d. Overhead conveyor
20. AGVs (automated guided vehicles) are
- a. Powered driverless trucks controlled by computer
 - b. Powered pallet trucks
 - c. Powered overhead cranes
 - d. Powered forklift trucks
21. Emphasis for warehousing has now shifted and become focused on:
- a. Meeting the requirements of customer service standards
 - b. Reduce the inventory
 - c. Increase the efficiency of material handling equipments
 - d. Increase the storage space
22. Moving goods over short distances into, within, and out of warehouses and manufacturing plants is called:
- a. Inventory expediting
 - b. Material handling
 - c. JIT inventory management
 - d. Inventory management
23. One of the warehouse performance metrics is
- a. Cost reduction in material
 - b. Cash-to-cash cycle time
 - c. Shipping accuracy
 - d. Production cycle time
24. One of the functions of a warehouse is
- a. Assembling

- b. Machining
- c. Picking
- d. Driving a fork lift

25. Which activity cost holds the major cost in warehousing activity?

- a. Receiving
- b. Storage
- c. Put away
- d. Picking.

26. Inspection is involved in which activity

- a. Cross-docking.
- b. Receiving.
- c. Picking.
- d. Storing.

27. Assigning of materials in warehouse based on

- a. ABC
- b. VED
- c. FSN
- d. HML

28. Which activity holds the major time in performing operations in warehouse?

- a. Put away
- b. Receiving
- c. Picking
- d. Storing.

29. Back order means

- a. Order not fully serviced.
 - b. Customer order delivered in proper time.
 - c. Order to vendor.
 - d. Current order.
30. Bin card words relates to
- a. Card which shows supplier details.
 - b. Card which shows customer details.
 - c. Card which shows transporter details.
 - d. Card which shows product detail
31. Which color lines will use for warehouse layout.
- a. Red.
 - b. Blue.
 - c. Yellow.
 - d. Green
32. Pick list is used for generation of
- a. Customer Invoice
 - b. Supplier Invoice.
 - c. Transporter invoice.
 - d. Service provider Invoice.
33. Flat stock in warehouse refers to
- a. Items with high volume and more weight.
 - b. Items with high volume and less weight.
 - c. Items with less volume and more weight.

- d. Items with less volume and less weight.

1.13 Descriptive Questions

1. What is difference between public and private warehousing?
2. What are the advantages and disadvantages of public warehousing?
3. What are the advantages and disadvantages of private warehousing?
4. What are the functions to be performed in a warehouse?
5. Briefly describe about “cross-docking”?
6. What is meant by activity profiling in a warehouse?
7. Describe various storage systems used in a warehouse for different applications?
8. What are the factors to be considered in the selection of location of the warehouse?
9. Describe briefly about the qualitative factor rating method for the selection of location of a warehouse?

1.14 References

1. Edward Frazelle, World-Class Warehousing, Logistics Resources International, Atlanta, 1996.
2. Edward Frazelle, Supply Chain Strategy, Tata McGraw Hill, New Delhi, 2002.
3. Alan Rushton, J Oxley and Phil Crouche, The Handbook of Logistics And Distribution Management, 2nd Ed., Kogan Page, London, 2000.

“Go to the ant, consider its ways and be wise!

**It has no commander, no overseer or ruler
Yet it gathers its food at harvest” and stores its provisions for summer**

2. Introduction to Inventory Management

Inventory is a modern trend. For example, why does every car or a truck carry a spare tyre? It is because, in case of any puncture, the rider can change the tyre and immediately be on his way. He need not have to be stranded for a more stretched time. To avoid similar circumstances in business, companies carry inventory both for raw materials and finished goods.

We can say that Inventories are one of the main ingredients for any physical distribution system. We cannot distribute any product without any inventory. However, costs and investments are involved in inventories. They also directly influence the movement and transportation and cost. If inventory policy of a company dictates maintenance of large stocks, then transportation characteristic will be FTL (Full truck Load) shipments. This would result in economies of scale. The logistics manager is responsible for all these costs. Responsibility lies in him for making decisions concerning the size, depth or location of these inventories, the lot size, route and mode of transport. His primary objective should be in optimizing distribution costs. He has to find an economical balance between transportation and inventory cost where inventories represent an important alternative to creating time and place utility in the product.

Inventory management can be defined as the sum total of those related activities essential for the procurement, storage, sale, disposal or use of material. This can be understood by answering the following questions -when is a refrigerator not a refrigerator? In terms of physical distribution, a refrigerator is not a refrigerator when it is in Delhi, whereas when the demand is in Chandigarh. Further more, if the color required is grey and the refrigerator is blue then also the refrigerator is not a refrigerator. To conclude, utilities are created in goods when the right product is available at the right place, at the right time, at the right quantity and is available to the right customer. Inventory management deals itself with all these problems, placing importance on the quantities of goods needed.

Inventory managers have to keep stock when required and utilize available storage space resourcefully, so that the stocks do not exceed the available storage space. They are responsible in maintaining accountability of inventory assets. They have to meet the set budgets and decide upon what to order, when to order, how to order so that stock is available on time and at an optimum cost. Inventory managers have acknowledged that some of these objectives are contradictory; but their job is to achieve a economic balance between these conflicting variables. But to achieve this economic balance, a clear understanding of many interconnected variables is required -functions, types of costs, problems and the like. The following sections provide an insight into these variables. Further, it elaborates upon various aspects of inventory control in physical distribution system.

2.1 Role in the supply chain

Inventory exists in the entire supply chain because of disparity between supply and demand. This disparity is intentional at a steel manufacture where it is economical to manufacture in large lots that are then stored for future sales. The disparity is also intentional at a retail store where inventory is held in anticipation of future demand. An important role that inventory plays in the supply chain is to increase the quantity of demand that can be satisfied by having product ready and available when the customer wants it. Another significant role of inventory is to optimize cost by exploiting economies of scale that may exist during both production and distribution.

Inventory is spread across the entire supply chain from raw materials to work in process to finished goods that supplier, manufactures, distributors, and retailers hold. Inventory is a most important source of cost in any supply chain and it has an enormous impact on responsiveness. If we think of the responsiveness range the location and quantity of inventory can move the supply chain from one end of the spectrum to the other. For example, an apparel supply chain with high inventory levels at the retail store has a high level of responsiveness because a consumer can walk into a store and walk out with the shirt he is looking for. In contrast, an apparel supply chain with little inventory would be very unresponsive. A customer wanting a

shirt would have to order it and wait several weeks or even months for it to be manufactured, depending on how little inventory existed in the supply chain.

Inventory also has a major impact on the material flow time in a supply chain. Material flow time is the time taken between the points at which material enters the supply chain to the point at which it exits. Another important area where inventory has a significant impact is throughput. For a supply chain, throughput is the rate at which sales occur. If inventory is represented by I, flow time by T, and throughput by D, the three can be related using Little's law as follows:

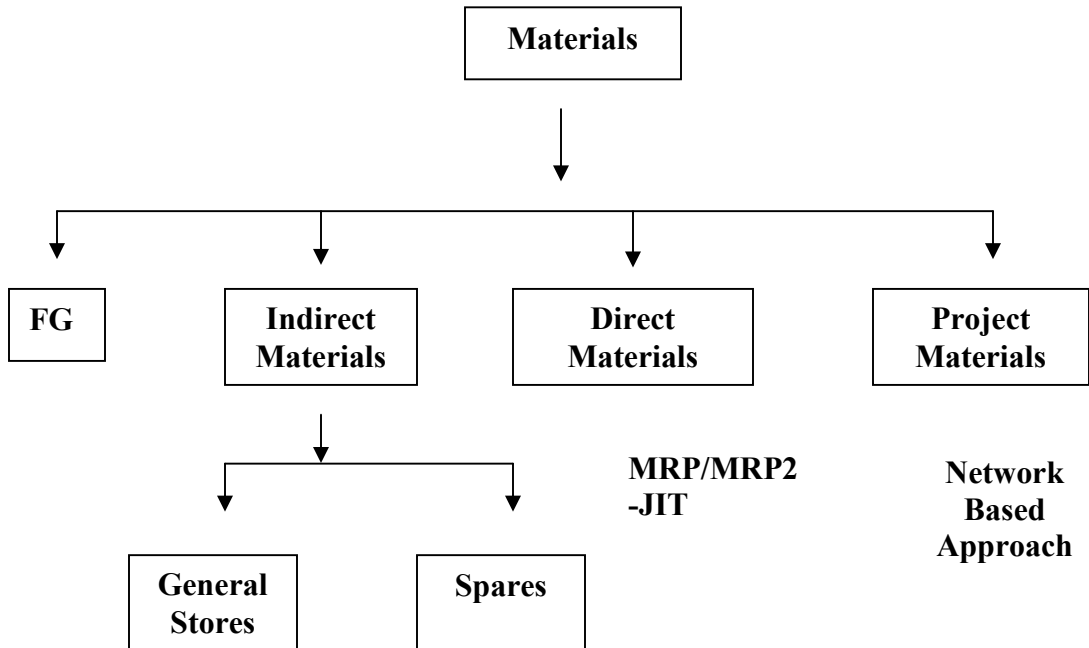
$$I = DT$$

For example, if the flow time of an auto assembly process is ten hours and the throughput is 60 units an hour, Little Law tells us that the inventory $60 \times 10 = 600$ units. If we were able to reduce inventory to 300 units while holding throughput constant, we would reduce out flow time to five hours ($300/60$). We note that in this relationship, inventory and throughput must have consistent units.

The logical conclusion here is that inventory and flow time are synonymous in any supply chain. Managers must use measures that lower the amount of inventory needed without increasing cost or reducing responsiveness, because reduced flow time can be a significant advantage in a supply chain.

2.2 Role in the competitive strategy

Inventory plays a important role in a supply chain's ability to support a company's competitive strategy. If a company's competitive strategy requires a very high level of responsiveness, a company can use inventory to achieve this responsiveness by locating large amounts of inventory close to the customer. Conversely, a company can also use inventory to make it more efficient by optimizing inventory through centralized stocking. The latter strategy would support a competitive strategy of being a low-cost producer. The trade-off implied in the inventory driver is between the responsiveness that results from more inventories and the efficiency that results from fewer inventories.

2. Role of Inventory Control:

- Replenishment systems
- ROL system
- Periodic review system
- Selective control methods

$$\text{ROI} = \frac{\text{PROFIT}}{\text{TOTAL ASSETS (FA+CA)}}$$

- **Materials account for nearly 50% of total costs**
- **Inventory accounts for nearly 75% of CA**

Achieving the objectives of inventory control will result in more return on capital which is the prime objective of an organization, whether commercial or industrial. The formula given above is useful in arriving at the return of investment.

Another measure of healthiness of inventory control is Inventory Turnover Ratio (ITR). It is the ratio of total sales during specific time period (generally 1 year) to average inventory on hand during that time period.

Inventory Turnover ratio (ITR) (Finished Goods)

$$= \text{Annual Sales} / \text{Average Inventory}$$

Inventory Turnover Ratio (ITR) (Raw Material)

$$= \text{Annual Consumption} / \text{Average inventory}$$

Example

The following table shows the sales and inventory details (in millions) of 3 sub assemblies A, B & C of a project.

Particulars	A	B	C	Total
Sales	320	40	2	362
Raw Material	31	5	4	40
Finished Goods	22	9	8	39
WIP	10	4	2	16
Others	17	2	2	21

$$\text{ITR (A)} = 320:80 = 4:1$$

$$\text{ITR (B)} = 40:20 = 2:1$$

ITR (C) = $2:16 = 1:8$ (Very Poor)

CHAPTER - 3

A very high inventory ratio is vital for the healthiness of an organization.

3. Functions of Inventory

Inventories have four functions. They are:

Minimize costs at acceptable inventory levels: Replacing inventories in exceptionally small quantities result in low investments but high ordering costs. Thus, a point has to be set where the total inventory carrying cost is bare minimum but the level of inventory is such that it does not effect the production or customer base.

Provide desired customer service level: Inventories offer service in terms of satisfying customer demand. Inventory influences the time and costs of service. The location of inventory determines the time in which the customer will be served while a company policies concerning the economic order quantity, safety stocks, placement procedures and time will determine the cost at which the customer will be served.

Couple successive operations or functions: The decoupling effect of inventories is apparent throughout manufacturing and distributions systems. Normally in the absence of inventories in a system, a demand by a customer triggers a chain reaction of demand at each preceding level, i.e. manufacturing and purchasing. But the customer does not have time or patience to wait for the chain reaction.

A small inventory requires frequent response rather than instant response from the transport system, where as, a large inventory reduces the need for frequent response and cost of transport system .The decoupling effect of inventories allows a physical distribution manager to choose amongst various inventory management policies.

Stabilize production and the labor force, thereby trying to reduce capital requirements: This function of inventories is more associated to the manufacturing process, though it influences the distribution function as well. If an inventory

management system takes responsibility of finished goods storage, then it has to provide storage facilities for higher levels of inventories. For example, seasonal products in many cases are produced all around the year to decrease investment in capital equipment. The stocks which come into existence are called anticipation stocks. But to produce or not to produce anticipation stocks is a manufacturing decision rather than a distribution decision.

3.1 Types of inventory

- **Raw Material Inventory**
- **WIP Inventory**
- **Finished Goods Inventory**
- **MRO Inventories.**

Raw Material Inventory

The materials, from which the final product of the company is made, are the raw materials. The material does not include any material that supports production; these materials are called indirect materials. But raw material is limited to the direct material (or) component that actually becomes a part of the final product. The steel used for automobile production is good example of a raw material kept in mind, though that the raw material of one industry is usually the finished product of another. Some of the raw materials may be available only seasonally, like cotton, sugar cane etc. There are certain raw materials which are governed by government control and quota system, like newsprint, coke etc.

The size of the raw material inventory is dependent upon factors such as

- internal lead time for purchase,
- supplier lead time,
- vendor relations,
- availability of raw materials,

- government import policy in the case of imported material,
- the annual consumption of the materials and
- the criticality of the material.

Some of the examples of raw material inventory are steel, wood, cloth or other materials used to make components of the finished product.

The reasons for keeping this inventory are:

- I. Seasonal factors of availability and price advantage.
- II. As protective buffer against:
 - a. Delays in supply
 - b. Change in production rates due to market fluctuations for the finished products, etc.

WIP Inventory (Work-In-Process Inventory)

All materials that have been transformed from their raw materials stage by some manufacturing process but are not final products are work in-process goods. Sometimes, what may appear to be a final product is still really an in-process good if the final production step is a packaging one. It is in-process until it is in the form that can leave the plant. WIP can be found on the conveyors, trucks, pallets, in and around the machines and in temporary areas of storage waiting to be worked upon or assembled.

In building a ship or boiler the raw material is held as in-process stock till the complete ship is made. This is true in most of the heavy Engineering industries like cement plant, chemical plant. Some time they dispatch sector by sector to the site to reduce the in-process inventory. In continuous process industries the amount of in-process held is optimum, which cannot be reduced or increased like in petroleum refining, cement manufacturing and chemical industries. Whereas in medium size

industries where batch production is predominantly adopted, the in-process inventory is very high. After each production process the materials wait for the next operation.

The size of the inventory is dependent on the production cycle time, the percentage of machine utilization, the make/buy decision of the company, and the management policy for decoupling the various stages of manufacturing.

The reason for keeping In-Process inventory is

- ✓ As liquid stock to cater for variety and shorten the manufacturing cycle.
- ✓ As protective buffer against production breakdowns, rejections etc.
- ✓ For economic lot production.

Finished Goods Inventory

Finished goods inventory consists of all the stock that is ready for dispatch. In a bottling plant for example, the finished products are the bottles of beverages that are in their cartons or cases and are ready for shipment. This finished goods inventory acts as a buffer between the production department and the marketing department. Higher the stock of finished goods, then the cost of inventory is high. If the stock level is low or nil then the customer service will be affected. This will damage the good will of the customer about the company and the product. The purpose of this inventory is to reach the market by constant supply through distribution channels. This is controlled by the marketing department. The stock that is to be held at the warehouses, with the distributors and with retailers will be different depending upon the sales rate.

In pharmaceutical industries, the finished product stock will be very high at the distributors and retailers level as they have to stock all types and brand of medicine with the risk of expiry dates. In case of daily newspapers there should be absolutely nil finished stock as its life is only one day.

The spares stock is also an important inventory. In this case, we may not know when and what part will be required and we have to stock all of the items. Statistical methods and good forecasting techniques only will help us in deciding the type and quantity of spares to be held in stock for sale.

The size of the finished goods inventory also depends on

- the ability of the marketing department to push the products,
- the company's ability to stick to the delivery schedule of the client,
- the shelf life and the warehousing capacity.

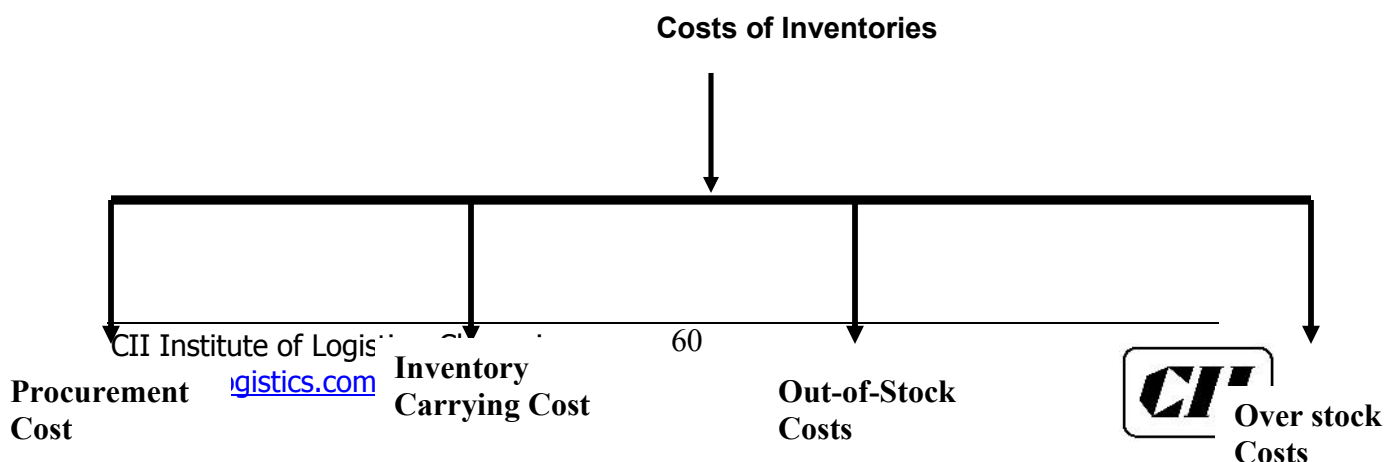
The other reasons for holding this inventory are

- To protective buffer against sales rate changes.
- To absorb economic production lots.
- To stabilize the level of production and employment when the sales is of a seasonal variety.

MRO Inventories

Maintenance, repairs and operating supplies which are consumed during the production process and generally do not form part of the product itself (e.g. oils and lubricants, machinery and plant spares, tools and fixtures, etc) are referred to as MRO inventories

3.2 Inventory Cost



Order

Cost or Procurement Cost

Procurement cost is the total cost incurred during the ordering of an item. These costs are not connected with the quantity ordered but primarily with physical activities required to process the order.

For **purchased items**, these would include the cost to enter the purchase order and/or requisition, process involved in getting the approval of the purchase order, the cost to process the receipt, raw material inspection, invoice processing for vendor payment, and in some cases a portion of the inbound freight may also be included in procurement cost. It is important to understand that these are costs associated with the frequency of the orders and not the quantities ordered. For example, in your receiving department the time spent checking in the receipt, entering the receipt, and doing any other related paperwork would be included, while the time spent repacking materials, unloading trucks, and delivery to other departments would likely not be included. If you have inbound quality inspection where you inspect a percentage of the quantity received you would include the time to get the specs and process the paperwork and not include time spent actually inspecting, however if you inspect a fixed quantity per receipt you would then include the entire time including inspecting, repacking, etc. In the purchasing department you would include all time associated with creating the purchase order, approval steps, contacting the vendor, expediting, and reviewing order reports, you would not include time spent reviewing forecasts, sourcing, getting quotes (unless you get quotes each time you order), and setting up new items. All time spent dealing with vendor invoices would be included in procurement cost.

Associating actual costs to the activities related with order cost is where many an EOQ formula runs afoul. Do not make a list of all of the activities and then ask the people performing the activities "how long does it take you to do this?" The results of this type of measurement are rarely even close to accurate. It was found it to be more effective to determine the percentage of time within the department consumed performing the specific activities and multiplying this by the total labor costs for a certain time period (usually a month) and then dividing by the line items processed during that same period.

It is extremely difficult to correlate inbound freight costs with order costs in an automated EOQ program and it only if the inbound freight cost has a noteworthy effect on unit cost and its effect on unit cost varies significantly based upon the order quantity.

In manufacturing, the order cost would include the time to initiate the work order, time taken for picking and issuing components excluding time associated with counting and handling specific quantities, all production scheduling time, machine set up time, and inspection time. Production scrap directly associated with the machine setup should also be included in order cost as would be any tooling that is discarded after each production run. There may be times when you want to artificially inflate or deflate set-up costs. If you lack the capacity to meet the production schedule using the EOQ, you may want to artificially increase set-up costs to increase lot sizes and reduce overall set up time. If you have excess capacity you may want to artificially decrease set up costs, this will increase overall set up time and reduce inventory investment. The idea being that if you are paying for the labor and machine overhead anyway it would make sense to take advantage of the savings in reduced inventories.

For the most part, order cost is primarily the labor associated with processing the order, however, you can include the other costs such as the costs of phone calls, faxes, postage, envelopes, etc.

Carrying cost.

Also called Holding cost, carrying cost is the cost associated with having inventory on hand. It is primarily made up of the costs associated with the inventory investment and storage cost. For the purpose of the EOQ calculation, if the cost does not change based upon the quantity of inventory on hand it should not be included in carrying cost. In the EOQ formula, carrying cost is represented as the annual cost per average on hand inventory unit. Below are the primary components of carrying cost.

- **Interest.** If you had to borrow money to pay for your inventory, the interest rate would be part of the carrying cost. If you did not borrow on the inventory, but have loans on other capital items, you can use the interest rate on those loans since a reduction in inventory would free up money that could be used to pay these loans. If by some miracle you are debt free you would need to determine how much you could make if the money was invested.
- **Insurance.** Since insurance costs are directly related to the total value of the inventory, you would include this as part of carrying cost.
- **Taxes.** If you are required to pay any taxes on the value of your inventory they would also be included.

Storage Costs.

Mistakes in calculating storage costs are common in EOQ implementations. Generally companies take all costs associated with the warehouse and divide it by the average inventory to determine a storage cost percentage for the EOQ calculation. This tends to include costs that are not directly affected by the inventory levels and does not compensate for storage characteristics. Carrying costs for the purpose of the EOQ calculation should only include costs that are variable based upon inventory levels.

If you are running a pick/pack operation where you have fixed picking locations assigned to each item where the locations are sized for picking efficiency and are not designed to hold the entire inventory, this portion of the warehouse should not be included in carrying cost since changes to inventory levels do not affect costs here. Your overflow storage areas would be included in carrying cost. Operations that use purely random storage for their product would include the entire storage area in the calculation. Areas such as shipping/receiving and staging areas are usually not included in the storage calculations. However, if you have to add an additional warehouse just for overflow inventory then you would include all areas of the second warehouse as well as freight and labor costs associated with moving the material between the warehouses.

Since storage costs are generally applied as a percentage of the inventory value you may need to classify your inventory based upon a ratio of storage space requirements to value in order to assess storage costs accurately. For example, let's say you have just opened a new E-business called "BobsWeSellEverything.com". You calculated that overall your annual storage costs were 5% of your average inventory value, and applied this to your entire inventory in the EOQ calculation. Your average inventory on a particular piece of software and on 80 lb. bags of concrete mix both came to \$10,000. The EOQ formula applied a \$500 storage cost to the average quantity of each of these items even though the software actually took up only 1 pallet position while the concrete mix consumed 75 pallet positions. Categorizing these items would place the software in a category with minimal storage costs (1% or less) and the concrete in a category with extreme storage costs (50%) that would then allow the EOQ formula to work correctly.

There are situations where you may not want to include any storage costs in your EOQ calculation. If your operation has excess storage space of which it has no other uses you may decide not to include storage costs since reducing your inventory does not provide any actual savings in storage costs. As your operation grows near a point at which you would need to expand your physical operations you may then start including storage in the calculation.

A portion of the time spent on cycle counting should also be included in carrying cost, remember to apply costs which change based upon changes to the average inventory level. So with cycle counting, you would include the time spent physically counting and not the time spent filling out paperwork, data entry, and travel time between locations.

Other costs that can be included in carrying cost are risk factors associated with obsolescence, damage, and theft. Do not factor in these costs unless they are a direct result of the inventory levels and are significant enough to change the results of the EOQ equation.

Out of stock costs

These are the third category of cost associated with inventory. These are incurred when a customer places an order and the order cannot be filled from the inventory to which it is normally assigned. Costs are divided into main categories

- **Lost sales costs**
- **Back-order costs.**

Lost Sales Costs: These occur when the customer, faced with an out-of-stock situation, chooses to withdraw his order for the product. The cost is the profit that would have been made if the sale had occurred and the cost of negative effect that the stock out may have on future sales. The higher is the degree of substitutes available in the market, the higher is the cost. The lost costs are intangible and difficult to measure and usually estimated on the basis of personal perceptions of executives.

Back order costs : Back order costs assume that a customer will wait for his order to be filled so that the sales is not lost, only delayed. But these back-orders create clerical and sales costs for order-processing additional transport, which have to be

incurred to fulfill these back-orders out of course of normal distribution channel. These costs are fairly tangible and therefore measurement is simple. Typically, the effect of out of stock item will be proportional to circumstances and goods used for out-of-stock-item. For instance, if a company is out of stock of, let's say, a bolt it uses in production process, it may opt for use of similar bolt or an expensive bolt. The additional cost of this bolt will be referred to as out-of-stock cost. But in another case, if a company runs out of a raw material and the whole of production process is shut down, then the costs as a result of this production breakdown will be considered out of stock costs.

Over stock costs: Another category in which a company can incur is the cost concerned with the circumstances when the company is left with some stock on hand even after the demand for the product has terminated. The interpretation of this cost is proportional to whether the inventory is static or dynamic.

Static inventory is one which is replenished only once a year for example, a merchant who wishes to sell specialized diwali crackers, with very short shelf life, has a very limited sales season. The season is only a few days long and thus the replenishment of stock will have a next to zero salvage value.

Thus if he has too much stock he will suffer loss equal to cost of over stock. This will be the cost of over stock for a static stock.

Dynamic stock is one which can be replenished throughout the season for example; a departmental store which has dynamic stock will have a different over stock value. Let us say ABC departmental store sells various household items. One such item is towel. Thus any stock left can be carried forward to the next period and so is true for an indefinite period. Thus there will be no over stock cost. But if the product is a woolen fashion accessory then the product life cycle will be shorter. If only one order can be placed, then the problem will be of a static demand but if multiple orders can be placed then there will be no overstock cost until the last order period of the season. At this point of time, any stock will undergo drastic devaluation, and this will be termed as overstock cost.

It is to be remembered, however, that a company can incur either overstock cost or under stock cost at a given point of time, but not both simultaneously.

3.3 Need to hold Inventory

There are number of reasons why a company might choose or need to hold stocks of different products. In planning any distribution system it is essential to be aware of these reasons, and to be sure that the consequences are adequate but not excessively high stock levels. The main reasons for holding stock can be summarized as follows:

- **To keep down productions costs:** Often it is costly to set up machines so production runs need to be as long as possible to achieve low unit costs. It is essential, however, to balance these costs with the costs of holding stock.
- **To accommodate variations in demand:** The demand for a product is never wholly regular so it will vary in the short term, by season, etc, To avoid stock-outs, therefore, some level of safety stock must be held.
- **To take account of variable supply leads:** Additional safety stock is held to cover any delivery delays from suppliers.
- **Buying costs:** There is an administrative cost associated with raising an order, and to minimize this cost it is necessary to hold additional inventory. It is essential to balance these elements of administration and stock-holding, and for this the economic order quantity (EOQ) is used.
- **To take advantage of quantity discounts:** Some products are offered at a cheaper unit cost if they are bought in bulk.
- **To account for seasonal fluctuations:** These may be for demand reasons whereby products are popular at peak times only. To cater for this while maintaining an even level of production, stocks need to be built up through the

rest of the year. Supply variations may also occur because goods are produced only at a certain time of the year. This often applies to primary food production where, for example, large stocks result at harvest time

- **To allow for price fluctuations/speculations:** The price of primary products can fluctuate for a variety of reasons, so some companies buy in large quantities to cater for this.
- **To help the production and distribution operations run more smoothly:** Here, stock is held to 'decouple' the two different activities.
- **To Provide Customers with immediate service:** It is essential in some highly competitive markets for companies to provide goods as soon as they are required.
- **To minimize production delays caused by lack of spare parts:** This is important not just for regular maintenance, but especially for breakdown of expensive plant and machinery. Thus spares are held to minimize plant shutdowns.
- **Work in progress:** This facilitates the production process by providing semi-finished stocks between different processes.

3.4 Mechanics of Inventory Control

Inventory control consists of finding answers to three questions

1. Should this item be stocked at all?
2. If so, when to order it?
3. How much to order?

Though these are the questions the inventory control tries to answer more stress is upon the last two questions. This is so because, what to stock is the question of sales forecasting for the target market. No item, not even the cheapest item, should be

stocked without careful review. This should be a continuous process as the environmental which dictates supply of inventory and the demand environment keep changing continuously.

In many cases, managers answer these questions by following a rule of thumb on hunch basis (take decision based on gut feeling or experience). More likely than not, such decisions without proper evaluation prove to be wrong.

Suppose, a manager based on his hunch may decide to buy 5000 items of a product in stock once a month. This is so because the item costs only 10 paise. Error could be

- Increased order and acquisition cost
- Increased cost of transportation and packaging
- Increased receiving and inspection cost.

The cost will be twelve times higher, as compared to the situation if the stock is ordered once a year, i.e. Rs.6000 p.a

Let's assume another possible situation where hunch could prove strategically wrong. If the unit cost was high, i.e. Rs.1, 000/- and the company needed on an average 500 units p.m what can the manager do? He has two options- first is to order in larger lot sizes for a couple of months so that transport and order processing costs are economies. Secondly, he could order on a monthly basis. But the second would increase the transport and order costs and thus he will opt for the first option (following the rule of thumb), i.e. order in lots for six months.

Error could be

- ✓ Increased inventory carrying cost
- ✓ Increased risk of obsolescence and deterioration

Thus unplanned decisions could lead to stock –out, over stocking and therefore in reducing profits of the company.

These examples prove that inventory control is a very sensitive area. The decision should be taken in relation to the overall environment of inventory management rather than on the basis of hunches or rule of thumb. This is so because the environment of inventory management is very complex. For example, demand for a product can be predictable or uncertain. Customers may be small, medium or big and there may be total uncertainty about whether they will buy from you or someone else. Considering this uncertainty of the environment, quantitative tools must be used to exercise inventory control and answer the above questions.

When to Order?

Under the modern concept, inventory should directly contribute to profitability of the company and should be concerned with such matters as flow, lead times, storage costs, and acquisition costs, material handling equipment, preservation and packaging.

General levels of stock should be related to sales and production policies of the firm, in the same way specification is related to technical needs. The various levels of stocks are:

1. **Deficiency Level:** This means stock in hand is inadequate to meet the needs. Existence of this level indicates actual or potential out-of-stock situation. Orders are placed through a faster alternative source of supply.
2. **Exhaust bin level:** This is a point popularly known as out of stock. At this point, the storage bin is empty. Emergency measures are taken to stock the bin.
3. **Buffer stock or minimum stock level:** This is the level at which any further demands upon the bin will necessitate with draws from the reserve or buffer

stock, especially when demand is immediate and fresh deliveries will take time to arrive. Usually the goods are ordered through normal channels as soon as the inventory reaches this level.

4. **Danger warning level:** It is the point of no return. After this point, a stock – out is inevitable if delay occurs. A computer program can readily include warning levels. The level should be such that if there is a possible delay, the processing should reveal this in time and the manager should take one of the following actions:
- a. Find an alternative source of supply
 - b. Request sales department to warn their customers of possible delay in supplies.
 - c. Put extra pressure on the supplier

3.5 Selective Inventory Control

The same phenomenon is noticeable in inventories as well. One would find that 20 percent of the total stock contributes to 80 percent of the value. And these 20 percent are most crucial as far as companies production is concerned. Realizing this phenomenon, inventory control in its attempt to reduce the cost of inventory, adopts the policy of selective control. In selective control, inventory of high-value items is controlled because they give greatest returns. Also, not much care is assigned for the low-value items, because the returns are low.

Very broadly, selective control is divided into eight categories as **ABC, HML, VED, SDE, GOLF, FSN, SOS, XYZ**. These are summarized below

Classification	Stands For	Criteria
ABC	Always Better Control	Annual value of consumption of the

		items concerned
HML	High Medium Low	Unit Price of material (Opposite of ABC)
VED	Vital Essential Desirable	Critical nature of the component in respect to production
SDE	Scarc, Difficult to obtain and easy to obtain	Purchasing problem in regard to availability.
GOLF	Government, Ordinary, Local, Foreign	Source of material
FSN	Fast, moving, slow moving or non moving	Issues from Stores
XYZ	-----	Inventory Value of items stored

Reorder Level: The reorder point determines when a re supply shipment should be initiated. If the reorder point is set too low, stock out position might occur and if it is set too high over stock costs will be high. Moreover, high reorder point will lead to increased investment in inventory and increased inventory carrying cost. A number of systems have been designed to establish the reorder point. The basic reorder point formula is

$$R = D * T$$

Where

R = Reorder point

D = Average daily demand

T = Average performance cycle length.

Take for example; ABC industry has a demand rate of approximately 100 u/day and its performance cycle of 20 days. Then,

$$R = 100 * 20 = 2000 \text{ Units}$$

In this kind of system, an order of predetermined amount is made when the stock of an item falls below the reorder point. The above approach is satisfactory as long as both D and T are certain. But when there is an element of uncertainty in any of these elements, then an inventory buffer is necessary. This is called SS. Therefore,

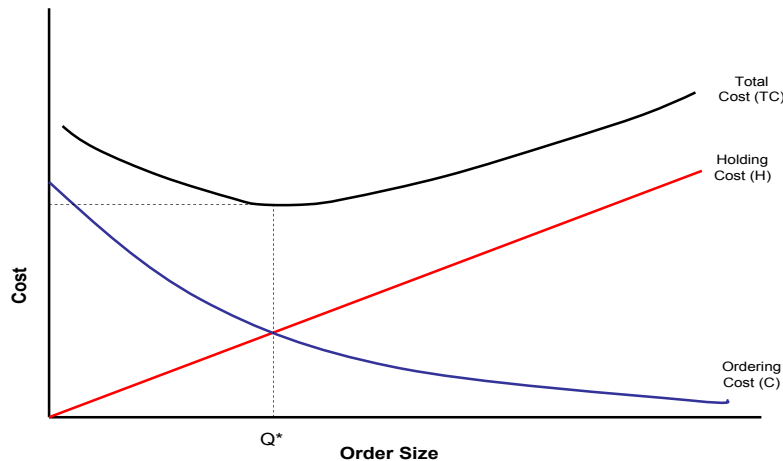
$$R = D * T + SS$$

Maximum stock level: This is the level above which the stock should not be permitted to rise. If permitted, it would increase the risk of loss due to deterioration, evaporation and obsolescence. It also will increase the capital tied up in the inventories.

Thus, when to order will be dependent upon the level of stock is in the bin. But knowing the level of stock is not enough. Efficient inventory control dictates that inventory level should be controlled.

How much to order?

This is a concept which tries to balance inventory and ordering cost. Practically, the two costs have inverse relationship. If the order quantity is larger, the order cost will be low but the inventory carrying cost will be high. The point at which two costs are minimum is the optimum point; here in figure the total cost is minimum. Every company should try to order this much quantity



Economic order quantity (EOQ) is the most useful techniques for determining “how much to order”? This method aims at determining the right quantity so as to ensure that the sum total of the two costs, i.e carrying cost and procurement cost are at the minimum point possible. The result of this effort is the “purchase of right quantity “.EOQ is that quantity at which the cost of procuring the annual requirements of an item and the inventory carrying cost are equal, i.e the total of the two costs is minimum. Mathematically, EOQ is represented by the equation

$$EOQ = \sqrt{2AP/UC}$$

Where

A = Annual Consumption in units.

P = Procurement cost per order.

C= Inventory carrying cost expressed as percentage (of value)

U = Unit price

Here's a table of EOQ worked out on the basis of rs.150 as purchasing cost

Per order and inventory carrying cost @ 30 per cent and unit value of one rupee

Working this out we have,

Annual Consumption in units	EOQ per Order	Number of orders per year	Period
1000	1000	1	1 Year
9000	3000	3	4 months
16000	4000	4	3 months
49000	7000	7	7.5 weeks
80000	9000	9	6 weeks
100000	10000	10	5.5 weeks
400000	20000	20	18 weeks

$$Q = \sqrt{2 * 80,000 * 150/1 * 0/100} = 8944 (9000 \text{ APPROX})$$

Therefore,

Requirement = $80,000/9000 = 9$ orders per year.

EOQ calculations are most helpful in establishing optimum inventory levels and effectively conserving the working capital invested in inventories. But in actual application EOQ faces certain objections.

These are as follows:

1. Often the inventory holding costs and the ordering costs cannot be identified accurately and sometimes cannot be even identified properly.
2. The EOQ as calculated is often an inconvenient number.
3. The use of EOQ usually leads to orders at random points in time so that suppliers receive an irregular stream of orders.

4. EOQ applied without due regard to the possibility of falling demand can lead to high value of obsolescent inventory.
5. EOQ may not be applicable when the requirements are irregular, or where there is impending price rise.

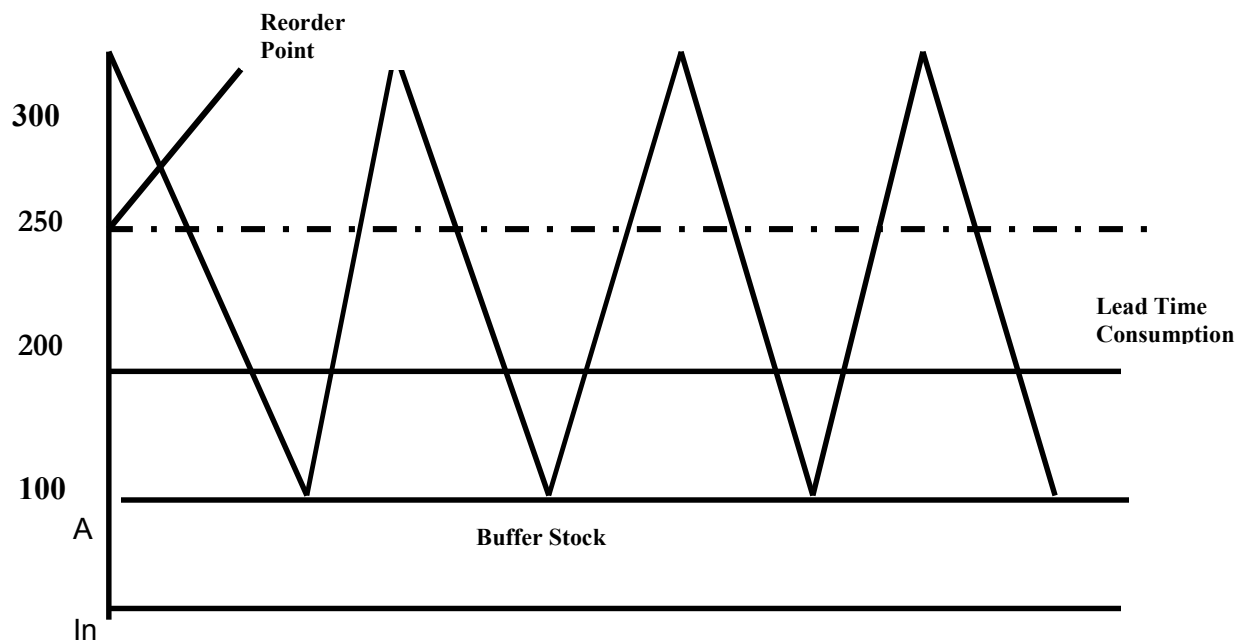
This is where human judgment comes in. The management techniques are not 100 percent fool proof. Every decision has to be taken in consideration of variables like volume, transportation rates, quantity discount, production lot size, capital limitation and so on. For this purpose though the extension of original EOQ formula are available yet judgment is crucial for interpretations of results.

4. Methods of Controlling Stock Levels

The basic approach to all inventory control methods is to establish a reorder level, which when reached means that the stock needs replenishment. The methods of controlling inventory levels are as follow:

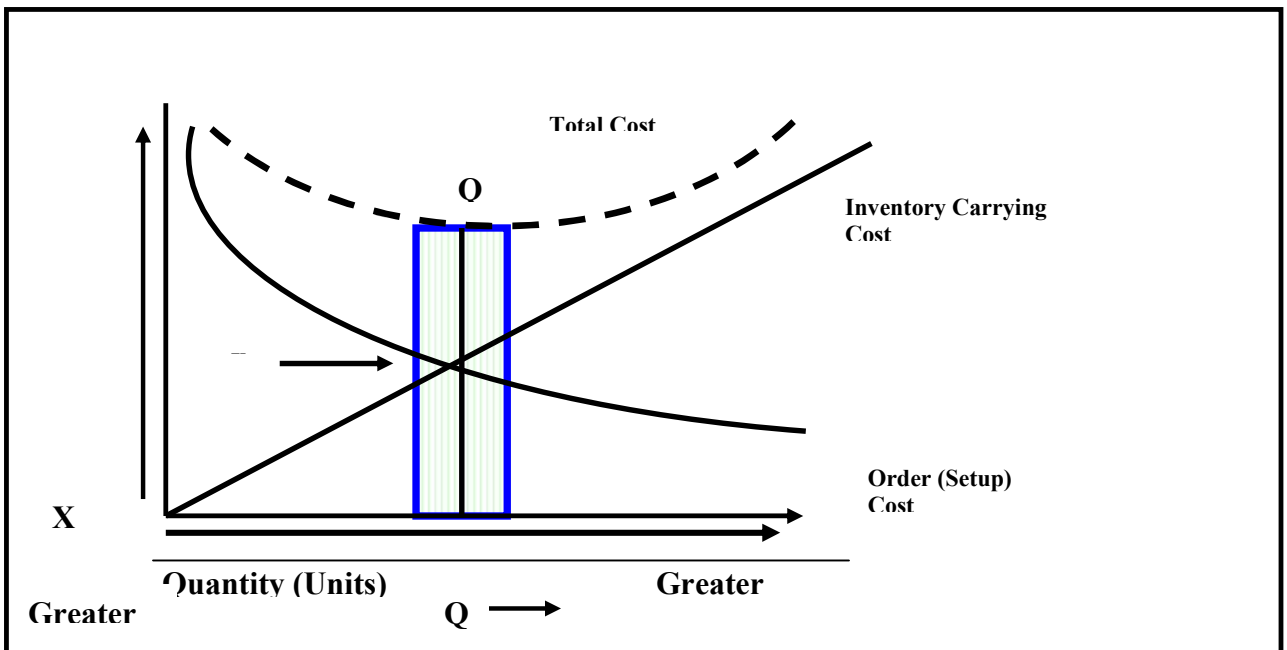
Re-order level system:

Figure shows a typical stock replenishment system. It represents a smooth average rate of consumption of 100 units per month. Supplies are obtained once in a quarter, i.e. three months consumption of 300 units. The minimum level (or safety or buffer stock) is fixed at 100 units or one month's consumption. The lead time, let's assume, in this case is 45 days. Thus, logically a company should re order the stock as soon as it reaches the level where the stock in the bin is equal to 45 days in other words, 250 units and is called reorder level. The maximum stock held by the company, according to this figure will be 400 units or, reorder level quantity (300) plus buffer stock (100).



In actual practice, one rarely gets a smooth consumption curve, as depicted here. Due to changes in condition of demand and supply, the consumption of the inventory also varies. Thus the rate of consumption of the inventory could be more than 100 units per month or it can be less than 100 units per month. The curve will sometimes dip into the buffer stock area and at others will be more than minimum level. However, in such cases, average inventory consumption can be taken to calculate the buffer stock levels and there is no problem once the buffer stock is achieved. The system is also known as the fixed quantity system.

a) Optimum Order Quantity: There are two major influences on the decision regarding quantity of product to order to accommodate the demand. First is the ordering cost and second, the inventory carrying cost. Because of the fixed nature of the ordering cost, it keeps on decreasing per unit as the order size increases. But this increases the time of storage for the quantity, i.e. It will increase the inventory conversion period (assuming constant rate of depletion).



As evident from figure the point at which the inventory carrying cost per unit purchased (IC) and order cost curve (S) intersect. To be precise, point X is equal to S/Q (order cost per unit of quantity purchased).

The average annual unit inventory cost at point

$$X = ICQ/2$$

Where

X = Average annual unit inventory cost.

I = Inventory Carrying cost as a percentage of unit cost.

C= Price per unit.

Q= Order Quantity in units.

The order cost (s) at point Q over the period of time comparable to inventory carrying cost for one year will be equal to

$$D * S/Q$$

Where

D = Annual rate of inventory depletion.

S= Order cost per order.

Because two levels are equal at point X, we have

$$ICQ/2 = DS/Q$$

Multiplying both sides by 2Q we get,

$$(IC)Q^2 = 2(DS)$$

$$Q^2 = 2(DS) / IC$$

$$Q^* = \sqrt{2 (DS)/IC}$$

Where

Q^* = Optimum order quantity.

Let's assume a manufactured item ZB. The manufacturing cost of this item is Rs.600. The carrying cost in the stock is 25 percent, i.e. Rs.150. The cost of placing an order is Rs.100. Assume the demand to be constant at 2/3 units per day, based on a lot size day week. The order quantity will be

$$\begin{aligned} Q^* &= \sqrt{2(DS) IC} \\ &= \sqrt{2 (208) (100)/.25(600)} \\ &= 16.7 \text{ Units approx } 17 \text{ Units} \end{aligned}$$

Where

$$DS = 2/3 * 6 * 52$$

Fixed time System: This is also called as constant cycle system. In this case, instead of considering the stock level we give more importance to time. Orders are placed at constant intervals to time. The quantities orders can change. Take the same example from re-order level figure. Here, the axis is showing the months in which the order was placed. Let's say the orders were placed on the fifteenth of February or may. Then it would be a fixed time system. But in the graph, both the systems are merged. The time of placement of order is 100 percent motivated by administrative convenience or the EOQ

Optimum Order interval: The optimum length of the order interval, for any item in an inventory is a function of demand rate, ordering cost, and inventory holding cost for the unit.

Mathematically it can be presented as,

$$Q^* = \sqrt{2DS/IC}$$

$$N^* = D/Q^*$$

Where N^* is optimum number of order placements in a time. Therefore,

$$Q^* = D/N^*$$

And

$$D/N^* = \sqrt{2DS/IC}$$

Thus

$$N^* = \sqrt{DIC/2S}$$

Expanding the example,

$$N^* = \sqrt{208 (.25) (600)/2(100)} = 12.5 \text{ units.}$$

I.e. orders should be placed every $313/12.5 = 25$ business days. (313 working days as six days a week)

Imprest stock control: This is the simplest method of inventory control and involves determination of a maximum level for the bin and a periodical inspection of stock levels in the bin. The bin is then filled up as required immediately to the maximum level.

Usually this system is restricted only to classification “c” materials – materials with relatively low value- whose lead time is minimum. For example, post offices. It is supposed to maintain a certain level of stamps for a fixed time period. After a week, the stocks are checked and the remaining items are ordered, so as to bring inventory back to maximum levels again.

Open access bins: Let’s assume a zee motor car company. It would be a waste of time and other resources if the same accounting procedure was maintained for nuts and bolts as is for tyres or engines. In the factory, the optimum procedure would be where the employees have accounted for access to engines and tyres but a free work point access to nuts and bolts. This is called open access bin.

This is used in combination with the Imprest system. The quantity replenished in this case is simply equal to quantity used

Two Bin Systems (Clerical method of inventory control): In this system, two bins are maintained by the companies which have different levels. When the first bin is exhausted, it indicated the time for replenishment. The second bin is like a reserve stock. The concept is similar to the petrol needle of a car. When the needle reaches the red segment of the gauge, the driver knows that the car is operating on reserve stock and it is time to replenish it.

In such cases as discussed so far, the formulae have been arrived at only because the forces of demand and supply were assumed to be predictable. It is fairly simple to determine various stock levels. In actual practice, however, such predictability is not always possible.

Just in Time Systems

- JIT focuses on minimizing the holding costs of stock
- Idea is that stocks are brought into the production process at the time they are needed
- Effectively an attempt to operate production with minimal / zero buffer stocks
- With JIT systems, production and purchasing are closely linked to sales demand on a week to week basis.
- Continuous flow of raw materials into stock
- When work in progress is completed, it goes straight to the customer

Requirements for JIT Systems

• Flexibility

- Suppliers and internal workforce need to be able to expand and contract output at short notice
- Need to be able to deliver supplies quickly and reliably

• High quality

- Raw materials must be of guaranteed quality
- Whole production process must focus on quality
- There are no/minimal buffer stocks should a batch of raw materials from a particular supplier prove faulty, or if they are damaged during the production process.

• Close working relationship with suppliers

- Often geographically close
- Joint approach to ensuring quality
- Systems need to be able to share information (e.g. sales data, purchasing requirements, delivery times)

Potential Benefits of JIT

- Lower levels of cash tied up in stocks (i.e. – lower Working capital)

- Reduction in stock holding costs
- Reduced manufacturing lead times
- Improved labour productivity
- Reduced scrap and warranty costs
- Price reductions on purchased materials
- Reduction in the time and cost of purchasing /accounting.

Pitfalls / Problems with JIT

- **Not suitable for many industries / organizations**

- Higher risk of stock outs E.g. critical medical supplies

- **Lots of potential problems for suppliers**

- Break in supply causes immediate problem for supplier to solve
 - May require new systems
 - Potential loss of reputation if supplier responsible for stopping whole of customer's production

- **Not something that can be done easily**

- Requires careful planning
 - Cannot be done overnight – production needs to move gradually towards minimal / zero buffer stocks
 - Often requires a substantial change in production culture.

5. Warehouse Management System (WMS)

The evolution of warehouse management systems (WMS) is very similar to that of many other software solutions. Initially a system to control movement and storage of materials within a warehouse, the role of WMS is expanding to including light manufacturing, transportation management, order management, and complete accounting systems. To use the grandfather of operations-related software, MRP, as a comparison, material requirements planning (MRP) started as a system for planning raw material requirements in a manufacturing environment. Soon MRP evolved into manufacturing resource planning (MRP II), which took the basic MRP system and added scheduling and capacity planning logic. Eventually MRP II evolved into enterprise resource planning (ERP), incorporating all the MRP II functionality with full financials and customer and vendor management functionality.

Now, whether WMS evolving into a warehouse-focused ERP system is a good thing or not is up to debate. What is clear is that the expansion of the overlap in functionality between Warehouse Management Systems, Enterprise Resource Planning, Distribution Requirements Planning, Transportation Management Systems, Supply Chain Planning, Advanced Planning and Scheduling, and Manufacturing Execution Systems will only increase the level of confusion among companies looking for software solutions for their operations.

Even though WMS continues to gain added functionality, the initial core functionality of a WMS has not really changed. The primary purpose of a WMS is to control the movement and storage of materials within an operation and process the associated transactions. Directed picking, directed replenishment, and directed put away are the key to WMS. The detailed setup and processing within a WMS can vary significantly from one software vendor to another; however the basic logic will use a combination of item, location, quantity, unit of measure, and order information to determine where to stock, where to pick, and in what sequence to perform these operations.

In today's competitive marketplace, the primary focus of many organizations is on improving customer service. To accomplish this, companies are embarking on a wide range of process-improvement initiatives. In many cases, increasing customer service levels involves adding personnel and increasing overall expenditures. Unfortunately, these additional expenses can erode profitability.

One proven method for increasing customer service without incurring additional long-term expenses is the implementation of a warehouse management system (WMS). The WMS concept and technology are not new. These systems have matured into time tested methods for reducing inventory costs while increasing overall efficiencies. Implementing WMS technology within an organization already using an ERP system allows that company to achieve a higher return on their software dollars and provide the best possible service to their customers

WMS can provide an organization with tangible benefits quickly, improving warehouse operations and increasing efficiencies without adding headcount. By implementing a WMS, a company achieves a number of dramatic benefits. They include:

- Directed put-away and directed order picking
- Warehouse capacity management
- Radio Frequency (RF) capability for data capture
- Load planning
- Cross docking
- Picking optimization
- ABC stratification
- Interleaving of work

Tangible costs:

CATEGORY	REASONS
Inventory reduction of up to 10% (one-time savings).	Inventory visibility and accuracy.
Reduced inventory carrying costs up to 35% (industry average).	Lower inventory levels; higher space utilization.
Reduced investment based on cost of money @ 8%	Reduced inventory.
Premium shipping costs	Reduced shipping errors.
Personnel handling paper - potential headcount reduction or resource redeployment*	WMS automates the management of order and priorities, eliminating paper.
Personnel handling order picking - potential headcount reduction or resource redeployment*	RF based picking productivity increases efficiencies.
Personnel handling shipping paperwork and confirmation - potential headcount reduction or resource redeployment*	Eliminate preparation work for shipping documents and ERP ship confirmations.
Eliminate physical inventory	Cycle counting will replace physical inventory requirement.

At a bare minimum, a WMS should:

- Have a flexible location system.
- Utilize user-defined parameters to direct warehouse tasks and use live documents to execute these tasks.
- Have some built-in level of integration with data collection devices.

Do You Really Need WMS?

Not every warehouse needs a WMS. Certainly any warehouse could benefit from some of the functionality but is the benefit great enough to justify the initial and ongoing costs associated with WMS? Warehouse Management Systems are big, complex, data intensive, and applications. They tend to require a lot of initial setup, a lot of system resources to run, and a lot of ongoing data management to continue to run. That's right, you need to "manage" your warehouse "management" system. An often time, large operations will end up creating a new IS department with the sole responsibility of managing the WMS.

The Claims:

WMS will reduce inventory!

WMS will reduce labor costs!

WMS will increase storage capacity!

WMS will increase customer service!

WMS will increase inventory accuracy!

The Reality:

The implementation of a WMS along with automated data collection will likely give you increases in accuracy, reduction in labor costs (provided the labor required to maintain the system is less than the labor saved on the warehouse floor), and a greater ability to service the customer by reducing cycle times. Expectations of inventory reduction and increased storage capacity are less likely. While increased accuracy and efficiencies in the receiving process may reduce the level of safety stock required, the impact of this reduction will likely be negligible in comparison to overall inventory levels. The predominant factors that control inventory levels are lot sizing, lead times, and demand variability. It is unlikely that a WMS will have a significant impact on any of these factors. And while a WMS certainly provides the tools for more organized storage which may result in increased storage capacity, this improvement will be relative to just how sloppy your pre-WMS processes were.

Beyond labor efficiencies, the determining factors in deciding to implement a WMS tend to be more often associated with the need to do something to service your customers that your current system does not support (or does not support well) such as first-in-first-out, cross-docking, automated pick replenishment, wave picking, lot tracking, yard management, automated data collection, automated material handling equipment, etc.

5.1 Setup

The setup requirements of WMS can be extensive. The characteristics of each item and location must be maintained either at the detail level or by grouping similar items and locations into categories. An example of item characteristics at the detail level would include exact dimensions and weight of each item in each unit of measure the item is stocked (cases, pallets, etc) as well as information such as whether it can be mixed with other items in a location, whether it is rackable, max stack height, max quantity per location, hazard classifications, finished goods or raw material, fast versus slow mover, etc. Although some operations will need to set up each item this way, most operations will benefit by creating groups of similar products. For example, if you are a distributor of music CDs you would create groups for single CDs, and double CDs, maintaining the detailed dimension and weight information at the group level and only needing to attach the group code to each item. You would likely need to maintain detailed information on special items such as boxed sets or CDs in special packaging. You would also create groups for the different types of locations within your warehouse. An example would be to create three different groups (P1, P2, P3) for the three different sized forward picking locations you use for your CD picking. You then set up the quantity of single CDs that will fit in a P1, P2, and P3 location, quantity of double CDs that fit in a P1, P2, P3 location etc. You would likely also be setting up case quantities, and pallet quantities of each CD group and quantities of cases and pallets per each reserve storage location group.

If this sounds simple, it is...well... sort of. In reality most operations have a much more diverse product mix and will require much more system setup. And setting up the physical characteristics of the product and locations is only part of the picture. You

have set up enough so that the system knows where a product can fit and how many will fit in that location. You now need to set up the information needed to let the system decide exactly which location to pick from, replenish from/to, and put away to, and in what sequence these events should occur (remember WMS is all about “directed” movement). You do this by assigning specific logic to the various combinations of item/order/quantity/location information that will occur.

Listed below are some of the logics used in determining actual locations and sequences:

Location Sequence. This is the simplest logic; you simply define a flow through your warehouse and assign a sequence number to each location. In order picking this is used to sequence your picks to flow through the warehouse, in put away the logic would look for the first location in the sequence in which the product would fit.

Zone Logic. By breaking down your storage locations into zones you can direct picking, put away, or replenishment to or from specific areas of your warehouse. Since zone logic only designates an area, you will need to combine this with some other type of logic to determine exact location within the zone.

Fixed Location. Logic uses predetermined fixed locations per item in picking, put away, and replenishment. Fixed locations are most often used as the primary picking location in piece pick and case-pick operations; however, they can also be used for secondary storage.

Random Location. Since computers cannot be truly random (nor would you want them to be) the term random location is a little misleading. Random locations generally refer to areas where products are not stored in designated fixed locations. Like zone logic, you will need some additional logic to determine exact locations.

First-in-first-out (FIFO). Directs picking from the oldest inventory first.

Last-in-first-out (LIFO). Opposite of FIFO. I didn't think there were any real applications for this logic until a visitor to my site sent an email describing their operation that distributes perishable goods domestically and overseas. They use LIFO for their overseas customers (because of longer in-transit times) and FIFO for their domestic customers.

Quantity or Unit-of-measure. Allows you to direct picking from different locations of the same item based upon the quantity or unit-of-measure ordered. For example, pick quantities less than 25 units would pick directly from the primary picking location while quantities greater than 25 would pick from reserve storage locations.

Fewest Locations. This logic is used primarily for productivity. Pick-from-fewest logic will use quantity information to determine least number of locations needed to pick the entire pick quantity. Put-to-fewest logic will attempt to direct putaway to the fewest number of locations needed to stock the entire quantity. While this logic sounds great from a productivity standpoint, it generally results in very poor space utilization. The pick-from-fewest logic will leave small quantities of an item scattered all over your warehouse, and the put-to-fewest logic will ignore small and partially used locations.

Pick-to-clear. Logic directs picking to the locations with the smallest quantities on hand. This logic is great for space utilization.

Reserved Locations. This is used when you want to predetermine specific locations to put away to or pick from. An application for reserved locations would be cross-docking, where you may specify certain quantities of an inbound shipment be moved to specific outbound staging locations or directly to an awaiting outbound trailer.

Nearest Location. Also called proximity picking/put away, this logic looks to the closest available location to that of the previous put away or pick. You need to look at the setup and test this type of logic to verify that it is picking the shortest route and not the actual nearest location. Since the shortest distance between two points is a straight line, this logic may pick a location 30 feet away (thinking it's closest) that

requires the worker to travel 200 feet up and down aisles to get to it while there was another available location 50 feet away in the same aisle (50 is longer than 30).

Maximize Cube. Cube logic is found in most WMS systems however it is seldom used. Cube logic basically uses unit dimensions to calculate cube (cubic inches per unit) and then compares this to the cube capacity of the location to determine how much will fit. Now if the units are capable of being stacked into the location in a manner that fills every cubic inch of space in the location, cube logic will work. Since this rarely happens in the real world, cube logic tends to be impractical.

Consolidate. Looks to see if there is already a location with the same product stored in it with available capacity. May also create additional moves to consolidate like product stored in multiple locations.

Lot Sequence. Used for picking or replenishment, this will use the lot number or lot date to determine locations to pick from or replenish from.

It's very common to combine multiple logic methods to determine the best location. For example you may chose to use pick-to-clear logic within first-in-first-out logic when there are multiple locations with the same receipt date. You also may change the logic based upon current workload. During busy periods you may chose logic that optimizes productivity while during slower periods you switch to logic that optimizes space utilization

5.2 Other Functionality/Considerations

Wave Picking/Batch Picking/Zone Picking. Support for various picking methods varies from one system to another. In high-volume fulfillment operations, picking logic can be a critical factor in WMS selection.

Task Interleaving. Task interleaving describes functionality that mixes dissimilar tasks such as picking and put away to obtain maximum productivity. Used primarily in full-pallet-load operations, task interleaving will direct a lift truck operator to put away a

pallet on his/her way to the next pick. In large warehouses this can greatly reduce travel time, not only increasing productivity, but also reducing wear on the lift trucks and saving on energy costs by reducing lift truck fuel consumption. Task interleaving is also used with cycle counting programs to coordinate a cycle count with a picking or put away task.

Automated Data Collection (ADC). It is generally assumed when you implement WMS that you will also be implementing automatic data collection, usually in the form of radio-frequency (RF) portable terminals with bar code scanners. It is recommended to incorporate your ADC hardware selection and your software selection into a single process. This is especially true if you are planning on incorporating alternate technologies such as voice systems, RFID, or light-directed systems. You may find that a higher priced WMS package will actually be less expensive in the end since it has a greater level of support for the types of ADC hardware you will be using. Some WMS products have created specific versions of programs designed to interface with specific ADC devices from specific manufacturers. If this WMS/ADC device combination works for your operation you can save yourself some programming/setup time. If the WMS system does not have this specific functionality, it does not mean that you should not buy the system; it just means that you will have to do some programming either on the WMS system or on the ADC devices. Since programming costs can easily put you over budget you'll want to have an estimate of these costs up front. As long as you are working closely with the WMS vendor and the ADC hardware supplier at an early stage in the process you should be able to avoid any major surprises here.

Integration with Automated Material Handling Equipment. If you are planning on using automated material handling equipment such as carousels, ASRS units, AGVs, pick-to-light systems, or sortation systems, you'll want to consider this during the software selection process. Since these types of automation are very expensive and are usually a core component of your warehouse, you may find that the equipment will drive the selection of the WMS. As with automated data collection, you should be working closely with the equipment manufacturers during the software selection process.

Advanced Shipment Notifications (ASN). If your vendors are capable of sending advanced shipment notifications (preferably electronically) and attaching compliance labels to the shipments you will want to make sure that the WMS can use this to automate your receiving process. In addition, if you have requirements to provide ASNs for customers, you will also want to verify this functionality.

Cycle Counting. Most WMS will have some cycle counting functionality. Modifications to cycle counting systems are common to meet specific operational needs.

Cross Docking. In its purest form cross-docking is the action of unloading materials from an incoming trailer or rail car and immediately loading these materials in outbound trailers or rail cars thus eliminating the need for warehousing (storage). In reality pure cross-docking is less common; most "cross-docking" operations require large staging areas where inbound materials are sorted, consolidated, and stored until the outbound shipment is complete and ready to ship. If cross docking is part of your operation you will need to verify the logic the WMS uses to facilitate this.

Pick-to-Carton. For parcel shippers pick-to-carton logic uses item dimensions/weights to select the shipping carton prior to the order picking process. Items are then picked directly into the shipping carton. When picking is complete, Dunn age is added and the carton sealed eliminating a formal packing operation. This logic works best when picking/packing products with similar size/weight characteristics. In operations with a very diverse product mix it's much more difficult to get this type of logic to work effectively.

Slotting. Slotting describes the activities associated with optimizing product placement in pick locations in a warehouse. There are software packages designed just for slotting, and many WMS packages will also have slotting functionality. Slotting software will generally use item velocity (times picked), cube usage, and minimum pick face dimensions to determine best location.

Yard Management. Yard management describes the function of managing the contents (inventory) of trailers parked outside the warehouse, or the empty trailers

themselves. Yard management is generally associated with cross docking operations and may include the management of both inbound and outbound trailers.

Labor Tracking/Capacity Planning. Some WMS systems provide functionality related to labor reporting and capacity planning. Anyone that has worked in manufacturing should be familiar with this type of logic. Basically, you set up standard labor hours and machine (usually lift trucks) hours per task and set the available labor and machine hours per shift. The WMS system will use this info to determine capacity and load. Manufacturing has been using capacity planning for decades with mixed results. The need to factor in efficiency and utilization to determine rated capacity is an example of the shortcomings of this process. Not that I'm necessarily against capacity planning in warehousing, I just think most operations don't really need it and can avoid the disappointment of trying to make it work. I am, however, a big advocate of labor tracking for individual productivity measurement. Most WMS maintain enough data to create productivity reporting. Since productivity is measured differently from one operation to another you can assume you will have to do some minor modifications here (usually in the form of custom reporting).

Activity-based costing/billing. This functionality is primarily designed for third-party logistics operators. Activity-based billing allows them to calculate billable fees based upon specific activities. For example, a 3PL can assign transaction fees for each receipt, and shipment transaction, as well as fees for storage and other value-added activities.

Integration with existing accounting/ERP systems. Unless the WMS vendor has already created a specific interface with your accounting/ERP system (such as those provided by an approved business partner) you can expect to spend some significant programming dollars here. While we are all hoping that integration issues will be magically resolved someday by a standardized interface, we aren't there yet. Ideally you'll want an integrator that has already integrated the WMS you chose with the business software you are using. Since this is not always possible you at least want an integrator that is very familiar with one of the systems.

A lot of other modules are being added to WMS packages to improve its performance. These would include full financials, light manufacturing, transportation management, purchasing, and sales order management. This is a unilateral move of WMS from an add-on module to a core system, but rather an optional approach that has applications in specific industries such as 3PLs. Using ERP systems as a point of reference, it is unlikely that this add-on functionality will match the functionality of best-of-breed applications available separately. If warehousing/distribution is your core business function and you don't want to have to deal with the integration issues of incorporating separate financials, order processing, etc. you may find these WMS based business systems are a good fit.

6. Independent Demand Systems

The current material flow and management systems in use at different factories are independent demand systems that are based on personal experience of the material managers. Several years ago independent demand inventory control systems were widely used in many manufacturing industries, but this technique leads to a large amount of inventory at the factories and is slowly becoming obsolete. On the other hand, dependent demand systems reduce inventory levels at the factory using new techniques, such as, supply-chain management and just-in-time supply. They are being successfully applied in manufacturing industries and could also present substantial benefits for the industry. This paper applies lean inventory control and supply chain management techniques to the current material flow and management system, and proposes an effective and efficient material supply management system that can be applied at any manufacturing facility.

The Manufactured industry scarcely uses available technologies and techniques for efficient material management. This industry stands to gain substantially by incorporating some of the more advanced and successful management techniques used by other industries for effective material management. Techniques such as lean production principles, supply chain management, and inventory control systems become essential in any efficient material management system.

Lean production techniques were developed to optimize a process by avoiding or reducing waste. Lean principles suggest that all processes can be divided into value adding and non-value adding activities. Waste is defined as an activity that does not add value to a product, and all such waste should be reduced or eliminated if possible. Some examples of waste in material management processes are: inventories, unnecessary processing, unnecessary transport of goods and material shortages. Well known terms in management, such as, just in-time delivery (JIT), time based competition, concurrent engineering, total quality management (TQM), process redesign, employee involvement, are all partial approaches to lean production. The

application of these relatively new ideas results in a delivery system that could be applied to all types of processes related with production and/or material management .

The Supply Chain Management is widely used for production and material management in other industries. It is defined as a system which encompasses all activities associated with the transportation and flow of information and goods from the raw material through to the end user as well as all information flows. A well developed supply chain management system must involve all people related to the material delivery process, such as, suppliers, manufacturers, distribution centers, retailers and customers.

The basic idea of any supply chain system is that effectiveness and efficiency can be improved by sharing information and by joint planning. The potential for the integration of the supply chain to improve profit and competitive position has been highlighted by past experiences and by experts.

The common example of any manufacturing industry's supply chain system involves a minimum of five levels: Suppliers, Material Requirement Planning (MRP), Master Production Schedule (MPS), Distribution Resource Planning (DRP), and customers .Any successful supply chain system needs sub-systems that could generate quick information flow, quick material flow, as well as systems that can facilitate both quick information flow and material flow.

Inventory control systems were developed to provide a buffer between variable and uncertain supply and demand. Its primary goal is to provide this buffer at a minimum stock level and for a minimum cost. The material flow and management system used by the Manufacturing industry can be considered as an independent demand system. Such a system considers that demand for an item is independent of the demand of any other item and uses mathematical and quantitative models to relate forecast demands, order sizes and cost. These systems work well in retail industries, but present several drawbacks when dealing with batch production. Independent systems can use either fixed order quantities or periodic reviews to satisfy the demand. Fixed order quantity systems place an order of fixed size whenever a stock falls to a certain level. They are better suited for relatively expensive items with low but irregular demand. Periodic

review systems place order of different size at regular intervals to raise the stock level to a specified value, and they are better suited for low-value items with high but regular demand.

Currently, independent demand systems are being replaced by dependent demand inventory systems. These systems are used when the demand for materials is directly linked to the production plan. They use production and operation schedules to calculate stock requirements. Due to these specific characteristics, dependent demand systems are more suitable for the manufacturing industries. Stocks are controlled by “pull” demand rather than “push” demand. Two approaches for dependent inventory systems include: Material Requirement Planning (MRP) and Just-in-Time (JIT). The JIT system was developed to minimize the stock of material by having them arrive just as they are needed.

JIT was invented in Japan where it is widely used in assembly industries. This type of system needs intensive planning and communication between people involved in the process.

This paper uses the techniques described above and adapts them to the specific needs of the Manufacturing Industry. The current material management system used by the industry has been improved and activities and resources previously unconsidered have been added to the current system in order to complete the entire material supply chain. Finally, it proposes an efficient material supply chain management system based on dependent demand systems as an alternative to the current material management system based on independent demand systems. Such a system can be effectively utilized at any Manufacturing industry.

Uncertainties in the Material Management System

While the material delivery and control system used in this industry is functional, it presents many deficiencies that can be improved. There is no standard material flow and management system, which makes the purchasing manager indispensable. As a result of which, each factory has its own system based on the purchasing manager's experience instead of using a standard inventory control system. Furthermore, the lack

of knowledge about management techniques and available tools make the current process slow and inefficient, leading to higher amount of inventory and large storage areas at the facilities .

From the previous research efforts, a generic material flow and management system has been developed through questionnaires, personal interviews, and site visits. The key parties of the generic material flow and management system includes the material handlers, material supervisor and the purchasing manager. The material handlers move and store the material, whereas, the material supervisor checks quantities and quality of the material upon delivery and decides if the material is needed at the production station. The purchasing manager is responsible for the cycle counts, the tracking of inventory levels and records, and the quantity estimation and order of different materials.

As a result, many drawbacks associated with the generic material flow and management system have been identified. For example, there is no standard material management system. The purchasing managers have poor knowledge about inventory control systems so that most of material processes are done manually. Such a process consumes unnecessary time and resources as well as redundancy of information. In addition, multiple suppliers and production of various types of houses at a manufacturing industry makes it difficult to control constant inventory level and lead-time. The current system can be qualified as an independent demand system. It estimates the material requirement based on historical data instead of estimating directly from the actual demand. Sometimes the materials are also moved many times within the factory before they are actually used. All these cause irregular lead-time and high inventory level that result in unfavorable use of space and resources. Consequently, an advanced material flow and management system is needed that would incorporate the state of the art practices in material management.

7. Dependent Demand Systems

The system proposed in this module is based on dependent demand systems. These systems were developed to replace independent demand systems in manufacturing industries. The demand for material at manufacturing facilities is directly linked to the production plan. These systems use supply chain management concepts to estimate the material requirement directly from the different products manufactured at the facility and also backward scheduling to determine when the material needs to be ordered. This characteristic leads to a significant reduction in material stock.

Supply chain management is a concept poorly known in the Manufacturing industry environment, but it can be used to solve some of the biggest drawbacks detected within the current material flow and management system. An effective and efficient supply chain management system for the Manufacturing industry must consider 6 essential parties .Customers, Dealers, Distribution Resource Planning (DRP), Master Production Schedule (MPS), Material Requirement Planning (MRP), and Suppliers.

These key players are available at any Manufacturing facility, but are not efficiently utilized. MRP responsibilities can be fulfilled by the Purchasing Department, while MPS and DRP responsibilities can be satisfied by the Production Department and Sales Department respectively. Currently, these parties are considered as independent departments, but it is necessary to integrate them in order to design an efficient and effective supply chain management system. This integration will optimize and accelerate the flow of information and products across the supply chain. The new system proposes the use of the same parties that exist in any Manufacturing facility by adding responsibilities to each of them and optimizing the information flow. The proposed system is a leaner process avoiding unnecessary duplication and processing of information.

Parties within the System

It is important to define the role of each of the six parties within the system and how they support each process and add value to the entire material supply chain

management system. These parties need to work together and share information to lead to an optimum system.

Customers

The customers are the beginning and the end of the material process flow. They must be considered as part of the supply chain because they select the products that are going to enter the assembly line. The Manufacturing industry allows product customization; therefore they have the option to do small changes to the original product. These changes are only permitted for finishing because the layout and structure is standard.

Dealers

The dealers are the intermediates between the Manufacturing factory and the customers. It does not work directly with customers. All products that enter the production line are already sold, therefore the dealers are the ones who work with customers to define the specific characteristics of the house and then transmit this information to the Manufacturing factory.

Distribution Resource Planning (DRP) Department

The requirements of this department can be fulfilled by the sales department and is responsible for the logistic part of the process. They select the different dealers with whom the factory is willing to work. The information flow between these two parties must be efficient and a constant relationship between them needs to be created. The DRP department shares information on the range of products offered by the factory with the dealer so the latter can show them to the customers. The DRP receives the requirements from the dealers and transmits them to the production department in order to accomplish these demands.

Master Production Schedule (MPS) Department

This function can be fulfilled by the production department which is responsible for developing the master production schedule. MPS department must consider the requirement defined by the DRP department during the schedule development and then define when the product is going to be ready. The master plan schedule is shared with the MRP department in order for them to estimate the material requirements to support the production demand.

Material Requirement Planning (MRP) Department

The responsibilities of this department can be fulfilled by the purchasing department. It is responsible for selecting the different suppliers with whom the factory is going to work, keep track of the goods inside the factory, and order the different materials to support the production schedule. It uses the master production schedule by transforming it into a material need schedule.

Then this schedule and the inventory records are used to develop the material purchasing schedule. The purchasing schedule defines different material quantities and times when materials need to be ordered. Finally, the material orders are sent to the proper supplier. The MRP department is formed by material handlers, head receivers, and the purchasing manager.

Suppliers

The suppliers are the ones who produce or supply the different materials used by the Manufacturing factories, and send them to the facility. The relationship between suppliers and the MRP department must be strong in order to develop an efficient material delivery and control system. Suppliers must be involved in the inventory control system, and share the responsibility for keeping track of the material levels at the factories.

Activities of the Dependent Demand System

The activities of the new system have been developed from a material point of view; therefore some activities are explained considering only their influence in the material flow and management system. The material supply chain management system is broken down into two main activities: the material flow and the information flow system. Each of these activities is divided into different processes that define the complete material cycle for any Manufacturing factory.

This module focuses on the information flow system. The material flow inside the factory will be explained briefly while the information flow will be explained in detail, since the MRP activity is the most important activity of the system. The other activities feed the MRP department with the required information to estimate the material requirements at the factory.

Material Flow System

The material flow system considers all physical material movement. This system compiles not only the movement of material inside the manufacturing facility, but also the movement outside from suppliers to the factory. This system is divided into three sub-activities: material delivery, material inspection and storage, and material utilization. The people involved in these processes include suppliers, head receivers, and material handlers.

Material Delivery

This activity was not considered as part of the system by the Manufacturing industry, but it is part of the dependent demand system. Suppliers are responsible for this activity. It begins when suppliers receive the purchasing order from the MRP department. They process the order and produce or obtain the different items. The required material is transported to the manufacturing facility, where it awaits inspection.

Material Inspection and Storage

The depended demand system joins together the material inspection and material storage used in the current system and gives more responsibility to the head receiver who is in charge of the activity. The material inspection must be done by the head receiver and the suppliers. Inspection affect both, therefore it is in the supplier's benefit to help with this process. The material must be inspected considering three criteria: material type, quantity and quality. This process consumes time that must be considered inside the lead time, but it is essential to verify these criteria and compare them with the original order.

Once the material is accepted, the head receiver has to evaluate if the material is needed at the station or if it is going to be stocked. The material is normally moved to the main storage where the material is held until it is needed at the different stations. Finally, the head receiver updates the stock card and provides this information to the purchasing manager.

Material handlers use forklifts to supply material to different stations located in the assembly line. The material is supplied to each station when it is needed. The different materials are placed as near as possible to the working station in order to minimize the number of times the material is moved and also avoid wasting time required by the labor to look for the material.

Material Utilization

Once the material is placed at the proper station, it enters the manufacturing process. The material is used by the labor and it passes through all production steps in the assembly line. Finally, the house is finished and it is transported to the dealer.

Information Flow System

The information flow system includes all material related activities without the physical movement. These activities must be integrated in order to have an efficient information

flow system. The information shared by each part of the system is compiled by the MRP system which uses it to estimate the material required at the factory to support the production process.

Inventory Records

Inventory Records are used to keep track of the goods inside the Manufacturing facility. Every material that is stocked at the factory must be identified and have an inventory record available for use during the material estimation process. Inventory records for each material must include:

ID code, on hand, on order, lead times, and planning data Purchasing managers and head receivers are responsible for this activity. The head receivers update the stock cards upon delivery while purchasing managers update the inventory records and store them in a database for future use during the material estimation process.

Distribution Resource Planning (DRP)

The DRP process handles the logistics at any manufacturing facility, developing strategies to plan and set goals. An efficient DRP system in the Manufacturing industry must be able to answer three logistic questions that become the basis of any planning strategy that it needs to take.

From the material point of view, the DRP process becomes the first information chain inside a Manufacturing facility. The DRP receives the order from dealers and the information of any specific item the customer wants. Then, the DRP processes the order and sends it to the MPS, giving the required information to do the master production schedule. It can be concluded that the DRP is the customer of manufacturing.

Master Production Scheduling (MPS)

The job of the master production scheduling system is to plan the production so that the demand set by logistic can be satisfied. The MPS process is divided into two steps: the development of the master plan schedule and the estimation of the production rates required to satisfy the manufacturing demand.

A master plan schedule is a statement of what can and will be created by the Manufacturing facility. It becomes a realistic consensus between production and sales. This schedule indicates the date that different house models are entering the assembly line. Once the master plan schedule is updated, it is sent to the MRP department to be utilized for the material requirement estimation.

Material Requirement Planning (MRP)

The MRP process plans all items that need to be purchased and completed to support the master production schedule. In this manner, the replenishments can be planned and managed. Its principal goal is to reduce stock levels with consequent saving in capital, resources, and space.

This MRP system uses the information available at any factory and proposes the use of a computer database as a tool to optimize their utilization. It uses the information provided by the MPS department and the information compiled in the inventory records system. The MRP system is designed to use backward scheduling as the primary tool. The master schedule date becomes the end point and then all elements are offset backward in time. MRP completes the supply chain and uses the resources and information provided by the other parties to optimize the material order, delivery and therefore the production process. This process has been divided into three different steps described below:

- **Step 1: Material Need schedule.**

This step uses the master plan schedule to develop a material need schedule for the Manufacturing facility. The bill of materials and quantities that are used in each product is known, therefore the information needed to develop the material need schedule is available. This information is used to transform the master production schedule into the material need schedule.

- **Step 2: Purchasing Schedule.**

The second step in the MRP process is to use the lead time for each material to determine the material purchasing schedule. The lead time must consider also a material inventory holding time that needs to be defined by each factory. This additional time becomes a safety factor for the purchasing manager and it is used to assure that the material will be available for use when it is needed. The purchasing schedule will help the MRP department determine when the material needs to be ordered.

- **Step 3: Purchasing Orders.**

Finally, this purchasing schedule is converted into different purchasing orders with respect to the suppliers. These purchasing orders are completed with the supplier's contact information. Once these orders are ready, they are sent to the different suppliers. This step uses the existing database to relate the different materials with the different suppliers. The purchasing orders will answer the question where it is going to be bought.

MRP is a more efficient planning tool that can be used to propose back-up strategies when demand changes appear. Any changes to the master schedule automatically update the outputs of the system.

Material Process Flow

The entire material supply management system process is summarized. All activities are linked to each other forming the entire material cycle at any Manufactured Facility. Each individual step inside the process must be done efficiently to support the success of the entire supply chain. The process flow indicates the customers as the starting point and ending point of the material cycle.

7.1 Comparison between independent demand system & dependent demand system

The depended demand system has been compared with the standard system used in the Manufacturing industries. The depended demand system presents many advantages over current practices used by the Manufacturing industry. Some of them are described below:

- The depended demand system can be qualified as a pull system that uses backward scheduling as the primary tool by relating material requirement to the master production schedule.
- This system eliminates the need of historical data for material requirement estimation. Instead the material requirement is estimated directly from the products that the facility is producing. This system provides more accurate values and therefore it reduces wastage of material.
- It replaces a weekly order process with a daily ordering process, leading to lower levels of inventory at the facility, therefore improving the use of space at the Manufacturing factory.
- It eliminates unnecessary processes and redundant information making the system leaner.

- It introduces inventory control and supply chain management concepts to the Manufacturing industry opening a new frontier for further application.
- This new system solves the drawbacks detected in current practices by optimizing the use of information and available resources, and by radically reducing the process time of material requirement estimation.

A material supply management system has been developed from the standard material flow and management system currently used by the Manufacturing industry. This dependent demand systems integrates the different parties related with material management and proposes the use of modern practices for material quantities estimation.

In order to have an efficient material supply chain management system, the system must be supported by facilitators of quick information and material flow. Today, there are technologies available that can be used to accomplish this task. Internet, local networks and electronic data interchange (EDI) are being successfully used by many manufacturing industries, and they show potential benefits for the Manufacturing industry.

The depended demand system presents potential benefits to the Manufacturing industry by solving the problems detected in the current system. Experience shows that application of this type of system has brought several benefits in other manufacturing industries. The main advantage of the proposed new MRP system is its ability to relate demand for material directly to the master production schedule. This process reduces the amount of items on stock thus reducing holding cost and provides better planning.

Problems of the Generic Material Flow and Management System

1. No standard material management system exists
2. Redundancy of information.
3. Poor use of advanced technology.

4. High inventory levels resulting in waste of space, money and resources.
5. Difficulty to estimate amount of material needed due to various types of house.
6. Irregular lead times due to dealing with great number of suppliers
7. Dependence on historical data in estimating the material requirement
8. Employee's poor knowledge about inventory control

Inventory Records

Document	Description
ID code	An identification code.
On Hand	How many items are currently in stock available for using?
On Order	How many items have been already ordered from the suppliers and When they are due to arrive.
Lead Time	Time that takes between the order and delivery. A common error is not to include the time that takes the supplier to process the order and the time that takes the inspection upon delivery.
Planning Data	List of finished products. List of Materials. List of Suppliers. Material Quantities per House. List of Materials per supplier.

DRP Logistical, MPS, MRP Questions

Questions	Answers
DRP Questions	Different product models.

What am I going to sell? Where will I sell it? What do I have to get?	Interrelationship with the dealers. Product Type and specific items to produce.
MPS Questions What do I need to build? When do I need to build it?	Different product models. Date that the product is going to enter the assembly line.
MRP Questions What do I need to purchase? When do I need the material? How much do I need to buy? When do I need to buy them? Where will I buy them?	Different material to support the production process. A material need schedule at the facility. Material quantities needed to support the Manufacturing process. A purchasing schedule to support the demand. Different suppliers

Comparison between Independent and Dependent Demand Systems

Characteristics	Independent Demand System	Dependent Demand System
Inventory Control System	Push system	Pull system
Ordering System	Periodic Ordering System Weekly	Perpetual Ordering System Daily

People involved in the Process	Material Handlers Head Receivers Purchasing Manger	Customers Dealers DRP Department MPS Department MRP Department: Material Handlers Head Receivers
Activities	Material Flow: Material Inspection Material Storage Information Flow: Inventory Records Material Requirement Est.	Material Flow: Material Delivery Material Inspection & Storage Material Utilization Information Flow:
Inventory Records	On Hand On Order Historical Data	On Hand On Order Lead Time
Material requirement estimation	Historical Data	Directly from the product.
Stock	Higher Inventory Level	Lower Inventory Level
Technology used in the System	None	Computer Database Computer Software

References:

1. **Satish K.Kapoor, Purva Kansal** – Basics of Distribution Management, a logical approach, prentice-hall of India private limited, New Delhi, 2003.
2. **A.K.Datta** – Materials management, Processes, text and cases, second edition, prentice-hall of India private limited, New Delhi, 2000.

8.0 ABC Inventory Control

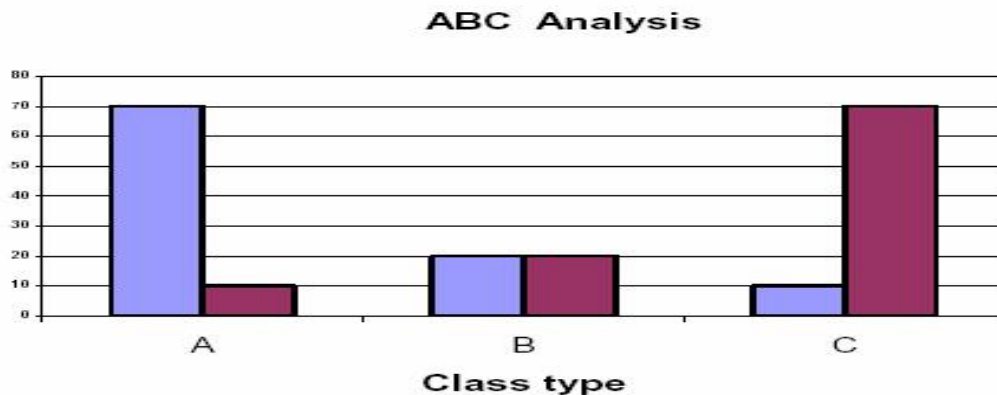
ABC analysis or Pareto's law is a well-known principle that is widely used for decision making and management control in many areas of management. Most researchers and practitioners are well aware of ABC analysis. However, textbooks and research articles are very brief and cryptic on how to use ABC analysis in practice. Moreover, textbooks in production management and logistics/distribution management are somewhat contradictory on how ABC analysis can be applied in the management and control of inventories. While logistics/distribution management textbooks suggest that the fast moving A items should be widely distributed (thus providing more availability or service level), production/operations management textbooks seem to suggest the exact opposite. They suggest that since the high dollar usage, A items account for a significant percentage of the inventory costs; the inventories of A items should be tightly controlled! This paper seeks to resolve and provide an explanation for this apparent contradiction. Thereafter, a framework is developed for choosing an inventory strategy based on ABC analysis.

ABC analysis is the process of dividing items in to three classes according to their dollar usage so that managers can focus on items that have the highest dollar value.

Class “A” items typically represent only 20% of the items but account for 80 % of the dollar usage. Class “B” items account for another 30% of the items but 15% of dollar usage. Finally, 50% of the items fall in class “C”, representing a mere 5 % of the dollar usage. (Figure1)

- **“A”** - items are the highest priority, the tightest control, frequent deliveries, close follow-up, and accurate records. Planning and Scheduling these parts utilize MRP (Material Requirements Planning), DRP (Distribution Requirements Planning, or EOQ (Economic Order Quantity) or other lot sizing techniques such as Lot for Lot. 10 % of the “A” items volume accounts for 70% of the total inventory value

- **“B”** - items are the priority when low or out of stock. Normal control is used and good
- records are maintained. EOQ and other lot sizing methods can be used effectively with these items. “B” items account for 20% of the total inventory value, and 20% of the inventory
- **“C”** - items are the lowest priority, simplest method of control. Min/Max used for ordering. These parts are usually expensed, as there are no records for them. These parts represent 10% of the total value, and 70% of the volume.



ABC Analysis

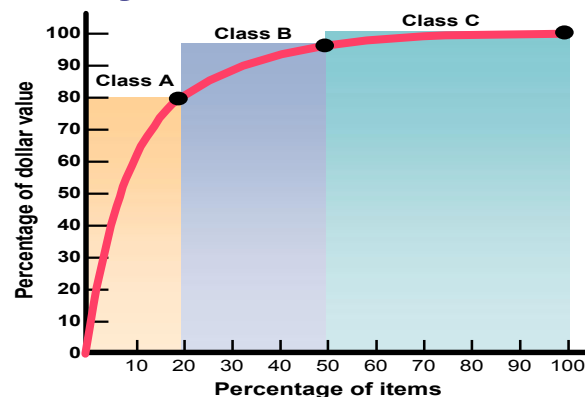


Fig 1 – ABC analysis

Managing Inventories by ABC:

ABC analysis is the method of classifying items involved in a decision situation on the basis of their relative importance. Its classification may be on the basis of monetary value, availability of resources, variations in lead-time, part criticality to the running of a facility, new customer parts unique to that product, and others.

Cycle inventory can be managed through ABC analysis:

“A” value items have to be counted more frequently i.e., once in a week to do accurate monitoring of these items which has more impact on the inventory value. “B” value items can be counted once in a month because they are moderate value items which have less impact on the inventory value. “C” items have to be counted once in three months or six months because they are least consumed value items and has very less impact on the inventory value.

Obsolescence budgeting also takes the management of ABC analysis into consideration.

“A” items have the most impact on the budget, if it is determined to be obsolete and scrapped from inventory. These parts may fool the reviewer because the “A” parts may not have a use for several years, but due to its critical importance may be needed at a later date. The slow moving activity report would not detect this need. Management and storeroom management need to consider all aspects of the parts before it is scrapped to obsolescence. ABC analysis puts a perspective that enhances this decision-making.

Other use of ABC analysis is in the reorganization of the storeroom.

Yearly, a review of parts storage areas needs to take place by the storeroom manager. In this analysis, ABC coding should be considered so that the “A” parts are continually being moved to the lower or easier access areas. “B” items are to be moved to middle areas, and “C” items placed in all other areas of the stores.

ABC analysis even affects lot-sizing considerations.

A plant using EOQ (Economic Order Quantity where a fixed order quantity is established that minimizes the total of carrying and preparation costs under conditions of certainty and independent demand.) uses ABC as well, so that inventory levels are minimized with the higher cost part. A review of the ABC Codes for the parts in stores should occur quarterly. Improper coding of parts may result in incomplete investigations of more expensive parts, improper storage, poor decisions on obsolescence and scrap, and less than adequate lot sizing.

ABC Code Management is an important tool for parts in storage. It puts a perspective on parts and emphasizes its value in relation to the quantity on-hand. Without this type of inventory management program in use, inventory decision-making would be based on just quantity alone. ABC management techniques methods involve both quantity and inventory valuation to make a more complete evaluation of parts in storage.

9.0 Multi-Echelon inventory systems

All inventories between a stage and the final customer are called the *Echelon Inventory*. Echelon inventory at a retailer is just the inventory at the retailer or in the pipeline coming to the retailer. Echelon inventory at a distributor, however, includes inventory at the distributor and all retailers served by the distributor. In a Multi-echelon setting, reorder points and order up to levels at any stage should be based on echelon inventory and not local inventory. Thus, a distributor should decide his safety inventory levels based on the level of safety inventory carried by all retailers supplied by him. The more safety inventory retailers carry the less safety inventory the distributor will need to carry. As retailers decrease the level of safety inventory they carry, the distributor will have to increase his or her inventory to insure regular replenishment at the retailers.

Consider a simple multi echelon supply chain with a supplier feeding a retailer who sells to the final customer. The retailer needs to know demand as well as supply uncertainty to set safety inventory levels. Supply uncertainty, however, is influenced by the level of safety inventory the supplier chooses to carry. If a retailer order arrives when the supplier has enough inventory, the supply lead time is short. In contrast, if the retailer order arrives when the supplier is out of stock, the replenishment lead time for the retailer increases. Thus, if the supplier were to increase his level of safety inventory, the retailer could reduce the safety inventory he holds. This implies that the level of safety inventory at all stages in a multi-echelon supply chain should be related.

If all the stages in a supply chain attempt to manage their echelon inventory, the issue of how the inventory is divided among various stages becomes important. Carrying inventory upstream in a supply chain allows for more aggregation and thus reduces the amount of inventory required. Carrying inventory upstream, however, increases the probability that the final customer will have to wait because product is not available at a stage close to him. Thus, in a multi-echelon supply chain a decision must be made with regard to the level of safety inventory carried at different stages. If inventory is very expensive to hold and customers are willing to tolerate a delay, it is better to

increase the amount of safety inventory carried upstream, far from the final customer, to exploit the benefits of aggregation. If inventory is inexpensive to hold and customers are very time sensitive, it is better to carry more safety inventory downstream, closer to the final customer.

The optimal deployment of inventory is a vital business function for an enterprise. The well-documented benefits of running a manufacturing, distribution or retailing operation with leaner inventory range from a permanent reduction in working capital to increased sales and higher customer satisfaction. As Forrester Research pointed out in a recent report, the ability to increase inventory turns is a key differentiator between highly successful and more poorly performing companies (e.g., Wal-Mart vs. Kmart; Dell vs. Compaq).

Managing inventory can be a daunting task for an enterprise with tens of thousands of products that are located in hundreds of locations. The challenge is even greater when the locations are situated in different tiers or echelons of the enterprise's distribution network. In such *multi-echelon networks*, new product shipments are first stored at a regional or central facility. These central facilities are the internal suppliers to the customer-facing locations. This is a common distribution model for many retail chains as well as for large distributors and manufacturers. For example, a large pharmaceutical wholesaler's distribution network consists of one regional distribution center (RDC) and more than 30 forward distribution centers (DCs). Another national retailer of automotive after market parts and equipment manages more than 25 million Stock-Keeping Units (SKUs) that are spread out across 10 DCs and more than 900 stores. And finally, a global manufacturer/distributor of furniture fittings carries inventory in European DCs located near its factories before shipping the finished goods to 15 local DCs worldwide; these DCs serve end customers.

Managing inventory in a multi-echelon network vs. a single-echelon network presents major pitfalls. One is the failure to achieve true network inventory optimization, because replenishment strategies are applied to one echelon without regard to its impact on the other echelons. A network view of inventory usage up and down the demand chain is absent when you are only dealing with a single echelon of locations.

Another pitfall is to base upper-echelon replenishment decisions on specious demand forecasts. These pitfalls can create substantial negative consequences, including the following:

- The network carries excess inventory in the form of redundant safety stock.
- End customer service failures occur even when adequate inventory exists in the network.
- Customer-facing locations experience undesirable stock outs, while service between echelons is more than acceptable.
- External suppliers deliver unreliable performance, because they have received unsatisfactory demand projections.
- Shortsighted internal allocation decisions are made for products with limited availability.

Managing Inventory in Multi-Echelon Networks

The complexities of managing inventory increase significantly for a multi-echelon distribution network with multiple tiers of locations (e.g., a network comprising a central warehouse and downstream customer-facing locations). All locations are under the internal control of a single enterprise. Instead of simply replenishing the warehouse or the DCs that sit between your supplier and your end customers, as in the single echelon situation, you also need to contend with the problems of replenishing another distribution point between your supplier and your DCs. For the purposes of this paper, we will refer to this additional distribution point as an RDC. The objective of multi Echelon inventory management is to deliver the desired end customer service levels at minimum network inventory, with the inventory divided among the various echelons.

9.1 Managing Inventory in Single-Echelon Networks

Before delving into the difficulties of managing the inventories in more than one echelon, let us review the single-echelon problem. In this environment, the distribution network is

Supplier - DC - Customers. *Table 1* describes the inventory drivers for a SKU that is located at a DC.

In this single-echelon situation, the lead times are between the DC and its external supplier. The enterprise's order supply strategies depend on its internal cost factors—such as those associated with handling and carrying inventory—and the external supplier's ordering constraints and bracket discounts. For this reason, the replenishment quantities depend on a combination of internal and external factors.

Inventory Drivers for a SKU Located at a DC:

Inventory	Description
Demand	Rate of product flow out of the DC
Demand Variation	Fluctuation of the product outflow from period to period
Lead Time	Expected time delay between ordering and having new product available to fulfill demand
Lead Time Variation	Fluctuation of the lead time from order to order
Replenishment Review Frequency	Frequency with which the DC checks its inventory position to see if a new order is needed
Order Supply Strategy	The DC's time supply objective, which depends on the economic trade-offs between carrying inventory, handling, transportation and purchase cost

Service Level Goal	The DC's service commitment to end customers
Inventory Position	The DC's available stock, taking into account the on-hand inventory, on-order quantities, back orders and committed stock

Table 1- Inventory Drivers for a SKU Located at a DC

9.2 Managing Inventory in Multi-Echelon Networks

Now consider the same product in a multi-echelon network that includes an RDC between the suppliers and the DCs. The same inventory drivers described in the preceding section apply for the SKU at the RDC location. However, some significant issues emerge:

- What is the proper measure of demand to the RDC, and how should this demand be forecasted?
- How do you measure the demand variation into the RDC?
- How does the trend toward larger orders from the RDC to the supplier affect the order supply strategy for the RDC SKU?
- What is the optimal service level goal between the RDC and its "customers," which are the DCs?
- How do you factor the individual DCs' inventory positions into the RDC replenishment decisions?
- How do the inventory drivers at the RDC, such as the replenishment review frequency and the service level goal, affect inventory and service levels at the DC level?
- When faced with a limited supply situation at the RDC, how should you allocate product down to the DCs?

Because the RDC also stocks inventory for the SKU, the replenishment decision at each DC also must address some *new* questions because of its relationship with an internal supplier:

- How will the ordering constraints imposed by the RDC (not the supplier) influence the DC's order supply strategy?
- How will different DC replenishment review frequencies and alternative order supply strategies affect the RDC? How do you factor the RDC service level goal into the DC replenishment strategy?
- To achieve the targeted service level commitment with its end customers, should the DC use the same service level goal when the RDC is available as a backup source for end customers?
- How can you use the RDC in an expedited ordering process?
- Do the external supplier lead time and lead time variation still play a role in the DC's replenishment strategy?

Figure 2 illustrates how the inventory drivers are linked in the two echelons. Circular nodes represent locations that are under the control of the one enterprise. The node labeled "DC" stands for *all* the DCs that stock the same product. The inventory drivers, denoted in red, are controllable by the enterprise. That is, the replenishment review frequency, the order supply strategy and the service level goal are replenishment control variables that a decision maker can set to influence the amounts of inventory to be carried and the service levels offered to downstream customers. The approaches for setting these control variables in the single-echelon case are well known, but how should you set the control variables in the multi-echelon case? Today, enterprises typically use one of two approaches:

1. Apply the single-echelon approach to each echelon in the network.
2. Use a distribution requirement planning (DRP) approach or a variation.

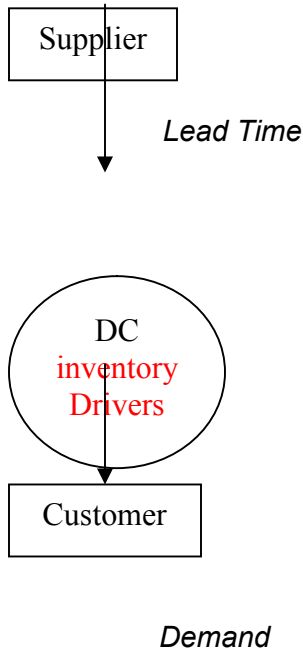
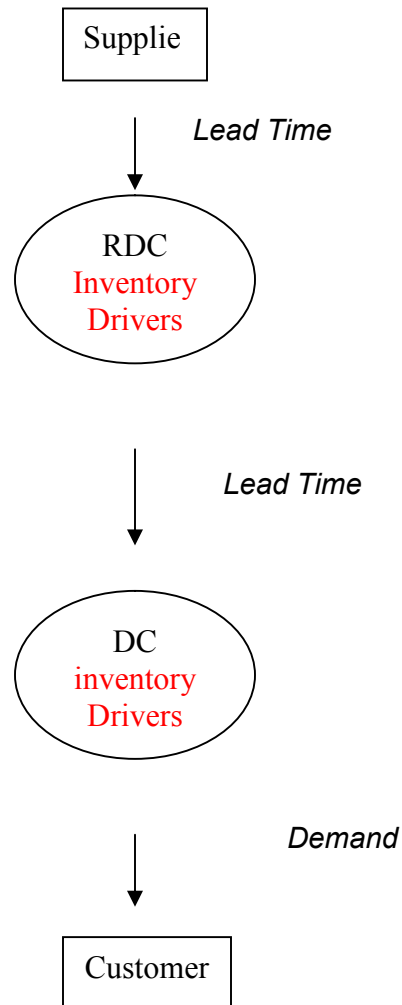
Single echelon**Multi-echelon**

Fig 2- inventory drivers in two different echelons

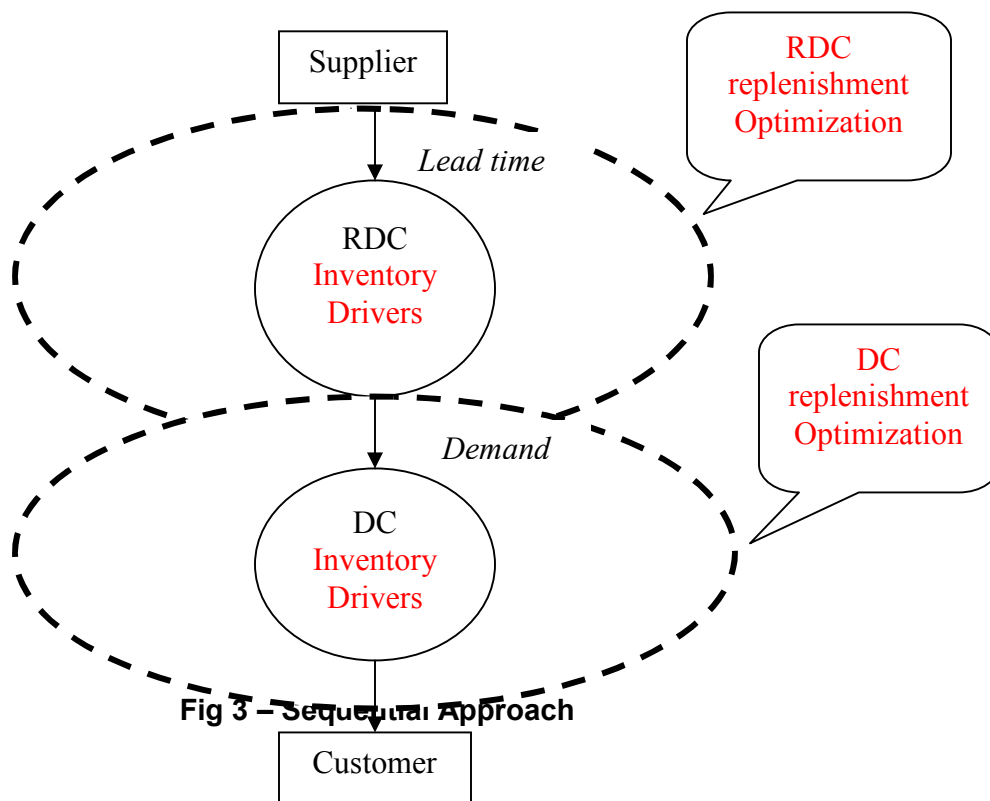
Using a Sequential Approach

The first method follows the obvious route. You take the established approach used in the single-echelon case and apply it twice—once to replenish the DCs based on their inventory drivers, and then again to replenish the RDC, based on its inventory drivers. In this case, the DCs would use the end customer demands and the RDC. DC lead

times. The lead times for the RDC are clear; they are simply the lead times to the supplier. But how should demand forecasts be created for the RDC? One way is to base demand on historical orders from the DCs to the RDC. Another way is to simply “pass up” the end customer demands from DCs. Both ways are flawed, as we shall see.

Figure 3 illustrates the DC and RDC replenishment approach that was just described. This is a *sequential approach* that splits multi-echelon replenishment into two separate challenges—one for the DC and one for the RDC.

Sequential approach



This approach presents the following problems:

- **Lack of visibility *up* the demand chain.** When a DC replenishes itself, it is oblivious to suppliers beyond the RDC. In particular, the DC ignores any lead times except the lead time from the RDC. The DC also assumes that the RDC will fill its replenishment orders completely every time. Finally, the DC has no visibility into the RDC's inventory balance.
- **Lack of visibility *down* the demand chain.** When the RDC replenishes itself, it is oblivious to customers beyond those of the DCs. In addition, the RDC has no visibility into the DCs' inventory balances or demands.
- **Demand distortion from the bullwhip effect.** Because the RDC and the DCs develop independent demand forecasts (based on their immediate customers' demands), the *bullwhip effect* causes increased demand variation between the RDC and the DCs. This results in unnecessary inventory at the RDC.
- **Total network costs remain unevaluated.** When the RDC's or the DCs' replenishment strategy changes (e.g., by altering one of the controllable inventory drivers), the cost implications of the new strategy on the other echelon are not considered. The focus is strictly on the impact on the echelon at hand.

Distribution Requirements Planning

The distribution requirements planning (DRP) approach is an extension of the materials requirements planning (MRP) method that manufacturers rely on to determine and satisfy requirements for the components used to assemble complex products. The parts or subassemblies used to make the finished product are dependent demand items. Instead of managing dependent demands in different stages of an assembly operation, as MRP does, DRP manages demands for a product that is located at different echelons of the distribution network. Demands for the product in a higher echelon are, in a sense, dependent on lower-echelon demands for the same product. With a DRP approach, DC-level demand forecasts are first used to develop gross product requirements. These forecasts are combined with safety stock requirements and stock status information to arrive at net requirements at the DCs.

This is analogous to an MRP master schedule. The time-phased dependent demand at the RDC is calculated by offsetting the DC net requirements by the RDC. DC lead times and summing over corresponding time periods. The RDC uses these “pass-up” demands to replenish itself.

The DRP approach has several major shortcomings. The No. 1 weakness is the deterministic perspective vis-à-vis pass-up demands and lead times. An immediate consequence of this is the subjective way in which the RDC safety stock is usually determined. Because the requirements passed up to the RDC include no uncertainty, there is no rigorous method for determining safety stock. This is why enterprises that use this replenishment method generally use rules of thumb for the RDC safety stock; this unscientific approach leads to excess inventory. It is not surprising that safety stock determination is somewhat loose—DRP has its roots in manufacturing, where production and transportation costs are of greater concern than inventory costs. Like the sequential approach, DRP fails to exploit visibility up the demand chain and lacks a network view of inventory optimization. In particular, there is no linkage between the safety stocks in the two echelons. Therefore, any attempt to optimally balance inventory between the two echelons is impracticable.

Assessing the Sequential and DRP Approaches

Both the sequential and the DRP approach result in excess inventory without necessarily improving service levels to the end customers. Although each echelon might be able to achieve reasonable results—from its own myopic viewpoint of the total problem—the results are not necessarily the optimal solution for the total network. That is, the total inventory of the RDC and at the DCs is not minimized in the pursuit of end customer service objectives.

Bullwhip Effect in Multi-Echelon Networks

Much has been written about the bullwhip effect and the way it distorts demand information as the information is transmitted up a demand chain. Although the bullwhip effect can appear in single-echelon situations, it is usually outside the enterprise's

control. However, this is not true in multi-echelon networks; in these cases, the enterprise must consider and manage the bullwhip effect. The bullwhip effect is caused by independent rational decisions in demand signal processing, order batching, reactions to price variations and shortage gaming. A sequential approach falls into the bullwhip trap by using multiple independent demand forecasts in different echelons. Order batching in a lower echelon causes extra demand variability between echelons. Finally, the lack of visibility up and down the demand chain in a sequential or DRP approach can produce inventory stockpiling to achieve customer service objectives. A multi-echelon network offers the opportunity to properly measure the bullwhip effect, to identify its root causes and to reduce or eliminate its impact on demand chain performance. To ignore this opportunity is to let the bullwhip effect degrade forecast accuracy, increase inventory, increase operational costs and lower customer service levels.

9.3 The True Multi-Echelon Approach

When an enterprise with multiple tiers of locations uses a true multi-echelon approach to manage inventory, the primary objective is to minimize the total inventory in all echelons (the RDC and all the DCs) while meeting service commitments to end customers. Even though inventory is the main focus, transportation and warehouse operations expenses also are kept in line, because their cost factors are part of the optimization. Both the sequential and the DRP approaches treat each echelon as a separate problem without considering the inventory impact one echelon may exert on another. With a multi-echelon approach, demand forecasting and inventory replenishment decisions are made at the enterprise level in a single optimization exercise rather than in a sequence of sub-exercises for each echelon. Specifically, a true multi-echelon approach should:

- **Avoid multiple independent forecast updates in each echelon.** The primary customer demand signal and other information at the DCs drive the forecasts in all echelons. A true multi-echelon approach eliminates the reliance on demands from the immediate downstream customer.

- **Account for all lead times and lead time variations.** In each echelon, the replenishment decisions account for lead times and lead time variations of all upstream suppliers, not just the immediate suppliers.
- **Monitor and manage the bullwhip effect.** The enterprise measures the demand distortion and determines the root causes for possible corrective actions.
- **Enable visibility up and down the demand chain.** Each echelon takes advantage of visibility into the other echelon's inventory positions—what is on hand, on order, committed and back ordered. At the DCs, this negates any need for shortage gaming. At the RDC, visibility into DC inventories improves projections of demand requirements.
- **Synchronize order strategies.** Synchronizing the ordering cycles at the DCs with RDC operations reduces lead times and lead time variation between the RDC and the DCs. Multi-echelon models can evaluate the impact on both echelons of different synchronization strategies.
- **Offer differentiated service levels.** The RDC can provide different service levels (for the same product) to different DCs. A multi-echelon approach makes this possible, because the enterprise controls how and when a product *enters* and *leaves* the RDC.
- **Correctly model the interactive effects of alternative replenishment strategies of one echelon on another.** Alternative strategies include different replenishment review frequencies, order supply strategies, service level goals and SKU stratifications.

Figure 4 illustrates how *all* of the inventory drivers in both echelons are factored into the DC and RDC replenishment decisions to truly optimize the network's inventory.

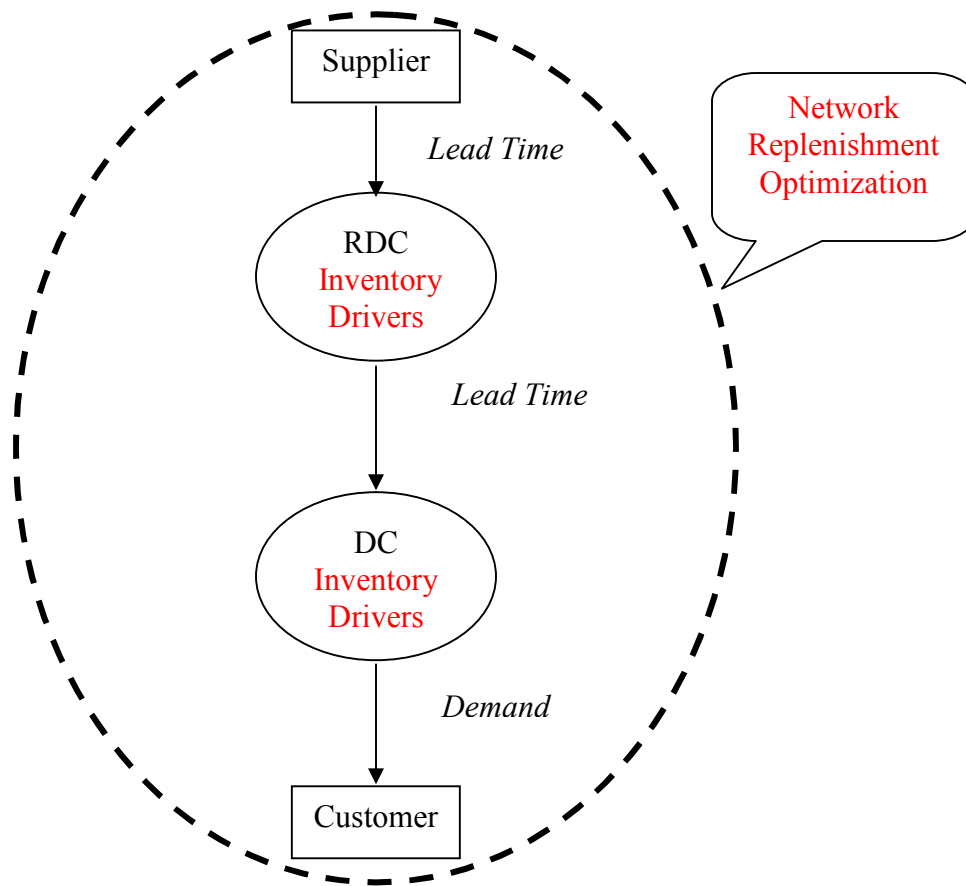


Fig 4 - Multi-Echelon Approach

Table 2 summarizes the key differences between the multi-echelon solution and other approaches.

Key Areas	Sequential Approach	DRP Approach	True Multi-Echelon approach
Optimization Objective	Meet immediate customer's (RDC or DC) service goals at minimum inventory; sub optimal for network	Not optimization; objective is to provide net requirements upstream to determine replenishment needs	Meet end-customer service goals at minimum inventory
Demand Forecasting	Independent forecasts in each echelon based on immediate customer's demands	Pass-up demands or projected orders with no measures of their variabilities	Forecasts based on lowest echelon's primary demand signals and other information; demand variations also are forecasted
Lead Times	Uses immediate suppliers' lead times and lead time variabilities	Uses immediate suppliers' lead times; ignores variabilities	Uses all lead times and lead time variations of upstream suppliers
Bullwhip Effects	Ignored	Ignored	Effects measured and accounted for in overall replenishment strategy

Network Visibility	<i>Immediate</i> downstream customers' demands and <i>immediate</i> upstream suppliers' lead times— <i>myopic</i> view of the network	Some downstream visibility; no upstream visibility	All echelons have complete visibility into other echelons; this visibility is exploited in the replenishment logic
Order Synchronization Between Echelons	Ignored	Maybe, probably not	Fully modeled to reduce unnecessary lags in network
Differentiated Customer Service	Not possible	Not possible	Achievable, as orders out of a higher echelon location to a lower echelon are fully controllable; allocation schemes using set-aside inventories can be used
Cost Implications Between Echelons	Not possible	Not possible	Fully modeled so true network optimization can be achieved

Case Study on an “ABC” company:

Until a few years ago, the network of “ABC”, a national wholesale distributor, comprised only DCs situated between “ABC” suppliers and customers. Each DC would order product from the suppliers and fill orders to customers. The DCs are customer-facing and have average service commitments of more than 98. A DC typically stocks between 25,000 and 50,000 SKUs. Today, “ABC” has several RDCs and the same DCs. Each DC is assigned to one of the RDCs. Every item that is stocked at a DC is either a *vendor-direct* or an *RDC item*. A vendor-direct item is replenished directly from an external supplier; it does not flow through any RDC. An RDC item at a DC is internally replenished from an RDC. Roughly half the company’s sales are tied to items that are stocked at both the RDC and DC echelons. An RDC stocks about 10,000 SKUs. Each RDC has its own customers that order directly from the RDC. These customers require 99% service levels. Thus, each RDC has two types of customers—external customers and internal customers represented by the DCs. Each DC orders from its RDC on a fixed schedule, but the external customers order any time they want. The lead times from the suppliers to the RDCs are generally shorter and less erratic than the lead times from the suppliers to the DCs had been before the RDCs existed. Instead of ranging from one to three weeks, the lead times are now three to 10 days. The time-definite deliveries between the RDCs and the DCs range from one to three days, depending on the DC.

Challenges

“ABC” end customers have very high service requirements. One way “ABC” can assure that it meets these high service goals is to carry extra inventory at the DCs. At the RDCs, inventories are carried to replenish the DCs and to satisfy the RDCs’ external customers. The problem is to deploy the optimal balance of inventory in the two echelons. “ABC” can use many control levers to shift the inventory balance between its RDCs and DCs. How “ABC” should set these to achieve service objectives at minimum inventory? Can slow-moving products simply be centralized at the RDCs with little or no product at the DCs?

The inventory management problem is further complicated because of the high service requirements of the RDCs' external customers. The RDCs must simultaneously set aside enough inventories to satisfy external customers' demands *and* to provide the DCs with enough products on hand to satisfy the DCs' customers' demands.

An overriding question "ABC" must address is how to come up with the right demand forecasts at the RDCs. These forecasts are crucial to replenishment decisions at the RDCs. Should the DC demands simply be passed up to the RDCs for use in determining statistical forecasts? Should the RDCs simply aggregate demand forecasts that are determined at the DCs? Should the RDCs develop statistical forecasts based on historical shipments to the DCs? What about historical orders from the DCs?

Other challenges exist. "ABC" needs to attain and fully exploit information transparency in its network. This means the RDCs and the DCs must freely share information on demand, inventory, in-transit orders and factors that impact demand, such as promotions activity. Another problem is to synchronize the replenishment activities between the two echelons to minimize lead times and to balance orders between DCs and RDCs over the days of the week. Failure to adequately tackle these challenges will lead to increased inventory and potential service failures because of the bullwhip effect.

Solution

"ABC" implemented a true multi-echelon inventory management system in phases, with each phase incorporating additional vendor lines. All replenishment decisions now exploit network visibility. The system models all cost implications of replenishment strategies at the DCs on the RDCs and vice versa. There are direct linkages between inventory drivers in one echelon and inventory levels in the other echelon. As an illustration, *Figure 4* depicts how "ABC" sets one of the control variables, the *RDC, DC service level goal*, to minimize the total inventory at the RDC and DCs. As expected, the RDC inventory increases as this parameter increases. Less obvious is the effect on DC inventories. As the expected fill rate from the RDC becomes larger, the total

inventory at the DCs decreases. The optimal setting for this parameter is the value that minimizes the total inventory in both echelons. Obtaining this optimal setting requires careful modeling of the interactive effects on both the RDC and DC safety stocks. “ABC” follows this optimization process for every RDC item.

Benefits

By using a true multi-echelon approach, “ABC” makes optimal replenishment decisions for all SKUs across every echelon. This enables the enterprise to attain or exceed service goals while driving down inventory requirements in the total network. Figure 5 illustrates a typical result for a class of SKUs with average velocity. Inventory is properly balanced between the two echelons to reduce network inventory by more than three days while maintaining or exceeding 99% customer service goals. Reduced inventories free up working capital for the enterprise. Besides increasing cash flow, the increased cash helps to permanently raise earnings for “ABC”. At the same time, higher service levels generate increased revenue and customer satisfaction.

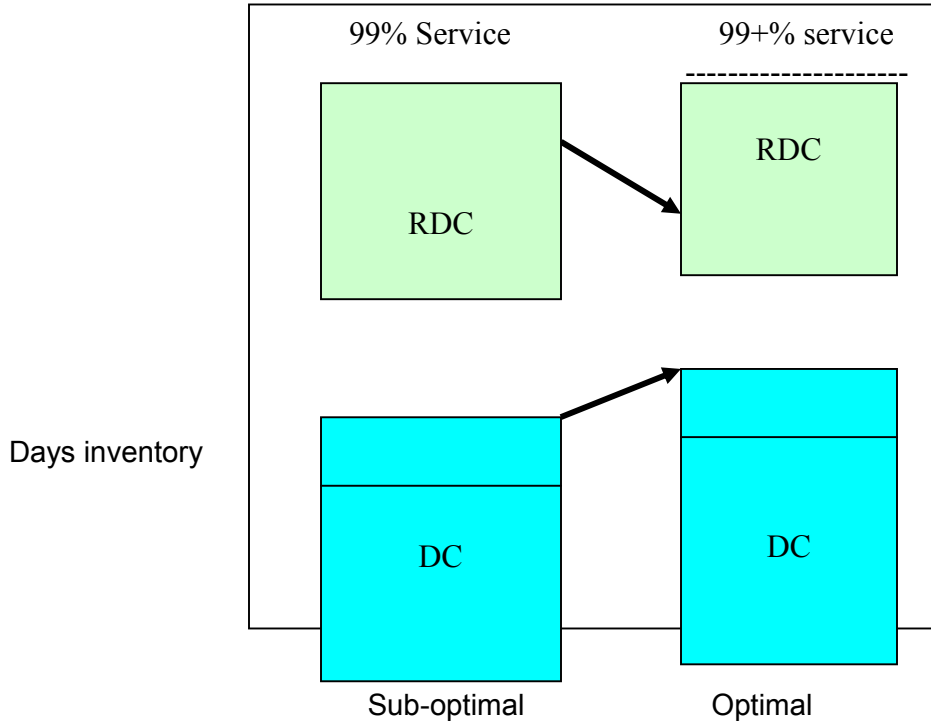


Figure 5: Driving Down Network Inventory with Multi-Echelon Optimization

Conclusion on the case study

A multi-echelon distribution network presents many opportunities for inventory optimization that the enterprise must pursue to offset potential increases in transportation, warehouse and occupancy costs. The key to achieving those savings is to use a true multi-echelon strategy to manage inventory. It is not a simple task to pursue such a strategy because of the multiplicities of inventory drivers and the complexities in modeling the interactions of the drivers between echelons. Nevertheless, the benefits are worth the effort. Taking the right approach can yield rewards on both sides of the inventory equation—better customer service with less inventory. Using a true multi echelon approach is the ultimate win-win strategy for inventory management.

10.0 The Principles and performance measures of Material Handling Systems

A number of different performance measures have been used in the design and analysis of material handling systems. These performance measures have measured either: (1) the entire manufacturing system (e.g. job throughput), or (2) the material handling system independently (e.g. vehicle travel distance). The following is a review of performance, reliability, and performability measures used in the analysis and design of material handling systems in a manufacturing environment.

The material handling system in any manufacturing setting plays an important part in the performance of the entire manufacturing system. Research in the design of material handling systems within a manufacturing environment has primarily studied system performance as a function of: (1) guide path design or layout (2) type of flow path (3) number of lanes in each aisle, (4) location of pick-up/delivery points, (5) fleet size, (6) unit load size, (7) vehicle speed and (8) queue capacity at each workstation. Research in the operation of these systems has primarily studied performance as a function of: (1) vehicle dispatching rules and scheduling, (2) idle vehicle positioning, (3) vehicle routing, and (4) zone definitions.

A number of different performance measures have been used in analyzing material handling system design and operation. However, the appropriateness and/or the adequacy of the performance measures used in material handling system analysis is rarely addressed.

A *performance measure* may be defined as a metric for quantifying efficiency and/ or effectiveness. As applied to material handling systems, the *effectiveness* of a material handling system describes to what extent the system performs the required handling tasks, whereas *efficiency* describes how economically (in terms of resource utilization) these tasks are performed. Thus, it is possible for an effective system to be inefficient; it is also possible for an efficient system to be ineffective.

1. Vehicle travel: Distance (or travel time)

Vehicle travel is generally measured as actual path distances, and not rectilinear or Euclidean distances. The total vehicle travel distance consists of loaded and empty vehicle travel. Material flow can then be characterized as either: (1) departmental (within departments) or (2) intra-departmental (between departments). Material flow within departments is usually not modelled in material handling system analysis.

The measurement of vehicle travel may include loaded vehicle travel, empty vehicle travel, or both. Vehicle travel distance is easily calculated when the flow volumes (trips required per unit time) and distances between stations are known.

Vehicle travel time directly corresponds to vehicle distance when: (1) the vehicle speed is constant or may be assumed to be constant, (2) the acceleration and deceleration effects are negligible, and (3) there are no delays due to blocking, queues or other congestion effects.

Another vehicle travel distance measure is the average loaded or empty vehicle travel. This measure is defined as the average time to complete a transportation task. A measure is also taken vehicle travel using the ratio (*RLE*) of empty versus loaded vehicle travel.

$$RLE = TL / TE$$

Where *TL* total loaded travel time,
TE total empty travel time.

2. Vehicle travel proportions

A vehicle may be in one of three states at any given time: (1) travelling loaded, (2) Travelling empty or (3) idle. Idle time spent in the parking area is used as a performance measure. Then, travel time percentages may be calculated as the

fraction of time that a device is travelling loaded, travelling empty, and waiting in an idle state. That is,

$$T = TL + TE + TI,$$

where

TI total idle time,

T total time,

TL as above (total loaded travel time),

TE as above (total empty travel time).

3. Vehicle travel: response time

Response time for a pick-up call is also considered as a performance measure. The authors define response time for a pick-up call as the time from when the pick-up request is made until the vehicle (starting from an idle and empty condition) arrives at the pick-up location. This measure differs from the total empty vehicle transportation time in that it consists of only empty vehicle travel when the vehicle starts from an idle position and does not include empty vehicle travel from a drop-off station to a pick-up station.

4. Handling time per job

The handling time per job is comprised of the time directly associated with material handling. This time includes: (1) the time the job spends in queues waiting for the material handling vehicle, (2) the total travel time, and (3) the total loading and unloading times, and (4) total vehicle blocking times. The total handling time per job includes the time from when a job enters the system until it leaves the system.

5. Vehicle utilization

Vehicle utilization may be used to determine the vehicle fleet size requirements for a system. Vehicle utilization may be based on: (1) the total vehicle mission time (including loaded and/or empty vehicle travel), (2) the loaded vehicle time and (3) the average of the time-averaged loads carried by all vehicles in the system. (Note: when

the vehicles are able to carry multiple loads, the utilization value may be larger than one.)

6. Number of loads completed

The number of loads completed is defined as the number of loads (or deliveries) completed over a period of time by all of the material handling vehicles. The number of loads completed is considered as a performance measure. Some industry measure the time required for the material handling system to deliver a specified set of loads.

7. Station queues: Mean load waiting times

The mean load waiting time is defined as the mean time loads wait in queues for material handling transportation. These queues are located either at processing stations

or at separate load transfer stations.

8. Station queues: Mean queue lengths

The mean queue length is the mean number of loads waiting for a material handling vehicle over a specific length of time. The variance of queue lengths may also be of interest, as a means of examining the adequacy of the physical space provided for the queue. Blocking occurs when a workstation's output queue (or buffer) is full and the Workstation can no longer place completed parts into this queue. Starvation occurs when a workstation's input queue is empty.

9. Material handling system cost

Material handling system costs may be comprised of variable and fixed costs. Variable costs are generally the operating costs of the material handling system. These costs can include the cost of power, lubricants, and maintenance. The variable costs may

also include the routing or travel expenses, which are proportional to the distance travelled.

Costs associated with idle or waiting vehicles may also be included in the variable costs. Fixed costs include such costs as the construction and purchase of equipment and hardware. The authors given below, in Table 5, use material handling system costs as a performance measure.

In addition to the use of *total* cost as a performance measure, cost ratio (C) is also used as a performance measure. This cost ratio is defined as:

$$C = C_{in} / C_{out}$$

Where

C_{in} moving cost of one unit load and one unit distance within a department, C_{out} moving cost of one unit load and one unit distance between departments.

10. Material handling system flexibility

Industry has identifies range and response as dimensions of flexibility. Range refers to how much the system can change. Response refers to how rapidly and cheaply the system can change. It has been defining material handling system flexibility as the material handling system's ability to reconfigure (to handle new material flows) and the material flow capacity. They define material handling system flexibility for a vehicle-based system as:

$$F_{mhs} = \sum_{i=1}^n x_i t_i e_i$$

where

x_i number of equipment of type i ,

t_i max unit load quantity factor, based on capacity of the equipment,

t_i equipment speed, based on the normal operating speed of the equipment,

e_i equipment loaded travel factor,

b i relative rerouteing cost, indicates ability of equipment to reconfigure.

11. Congestion

Congestion prevents vehicles from travelling freely on a guide path. As a result of congestion, vehicles may travel at reduced speeds or may be required to stop. Vehicles may be delayed by other vehicles blocking the path or at intersections. Congestion levels may be measured by the following quantities:

- Vehicle Blocking Time: the total blocking time of the vehicles is defined as the time where vehicles are unable to move due to other vehicles
- Track Blocking Percentage: track blocking is defined as the blocking time (as a percentage) for track segments due to vehicle interference
- Track utilization by averaging the utilization of all track segments and then dividing by the number of AGVs.
- Vehicle Waiting Time at Intersection: average vehicle waiting time at intersections

12. Congestion index

The congestion index (*I_c*) is defined as:

$$I_c = TA/TS$$

where

TA the actual travel time,

TS shortest travel time if there were no congestion.

Characteristics of effective performance systems

For most systems, the selection of performance measures is not simply a question of determining which measures are 'good' and which measures are 'bad', and selecting the 'best' one or the 'good' one. On the contrary, performance measure selection is the process of defining a set of measures that possess the following characteristics, all of which are found in any effective performance measurement system.

- **Inclusiveness:** The performance measure (or performance measurement system) should measure all pertinent aspects of the material handling system. In this way, good performance of one particular component of the system would not be possible without similar performance of other system components.
- **Universality:** The performance measurement system should allow for comparison under a wide range of operating conditions. That is, if two competing material handling system designs must be compared, then the measurement system should allow for this comparison, even if the system characteristics differ significantly.
- **Measurability:** All data required by the measurement system should be readily measurable. Furthermore, the process of measuring the performance of the material handling system should occur with a minimum of measurement errors and at a reasonable expense.
- **Consistency:** The performance measures used should be consistent with the overall goals of the organization. The value of the performance measure should therefore provide meaningful insights into overall material handling system performance with respect to organizational objectives.

Numerous performance measures have been used to analyse material handling systems. Although traditional manufacturing system measures, such as job throughput, have commonly been applied to material handling systems, they do not measure the material handling system independently. In these instances,

The performance of the material handling system is confounded with the performance of the manufacturing system. Thus, these traditional measures are not necessarily effective or appropriate in the analysis and design of material handling systems. Multiple performance measures provide more comprehensive information about system behaviour. In fact, the use of multiple performance measures results in more efficient and effective system designs and operation. Although multiple criteria decision making has largely been ignored as a decision tool, it has been established as the most appropriate method for the simultaneous consideration of multiple performance measures in material handling system design and analysis.

The reliability of material handling system components has largely been ignored in the literature, even though material handling system components are not completely reliable. Material handling systems are unique in the sense that they are degradable systems. That is, a failure of one or more material handling components does not necessarily indicate failure of the entire system. Indeed, system component failures may only indicate that the system will continue to perform its tasks, but at some reduced level of performance. Therefore, neither traditional notions of performance nor reliability alone are appropriate in this context. Performability measures, then, which simultaneously measure performance and reliability, emerge as appropriate measures for use in the design and analysis of material handling systems.

11.0 The fundamentals of various types of material handling equipment

“Every time you pick up an article without changing its form, you add to its cost but not to its value” – Mr. Henry Ford.

Materials Handling Systems (MHS) can be defined as “the set of all pieces of equipment that make possible the physical movement within the distribution chain – including the production chain and the warehouse – of raw material, work in progress and finished goods”. Therefore, materials handling systems perform a wide range of activities. In general, Materials Handling refers to the necessary tasks to be performed in order to move a load around the factory floor as well as to store and freight it. Materials handling takes place one way or another along all the links of the supply chain including production, distribution, and storage and retail functions.

Handling in a warehouse or distribution center will have a major impact on how effectively materials flow through the system, and on the cost, resource and time taken to get orders out to the customer. In addition, handling equipment can be capital – intensive, and the act of movement can be labour – intensive. Material handling equipment eases manual handling chores and enhances operational efficiency.

Various methods of handling goods are used in warehousing, from manual through to automated or robotic systems, and a broad categorization could be:

- Manual handling;
- Manually operated trucks and trolleys;
- Powered trucks and tractors, operator controlled and driven;
- Powered trucks and trolleys, driverless, computer-controlled;
- Crane systems;
- Conveyors;
- Robotics.

Although this chapter will concentrate on powered trucks, cranes, and conveyors, it must not be forgotten that there is a wide range of non-powered industrial trucks for pedestrian use. These include hand pallet trucks, order picking trolleys, stair climbing trolleys and wide range of platforms, shelf and cage trolleys.

Industrial lift trucks are used in warehousing for moving material over relatively short distances, for lifting into and out of storage, and for vehicle loading and unloading. Trucks facilitate load utilization, speed up movement, can handle large loads and consequently reduce the frequency of movements. Their lift ability enables the use of building height-the cost building volume reduces as building height increases.

The main types of powered trucks used in warehousing and stock yard operations are:

- Powered pallet trucks;
- Counterbalanced fork-lift trucks;
- Reach trucks including double reach and four –directional reach variants;
- Stacker trucks;
- High rack stacker trucks-very narrow aisle;
- Side loaders;
- Order picking trucks;
- Tugs and tractors;
- Straddle carriers-container handling

Non-powered hand trucks

Non-powered hand trucks are used in many situations. They are inexpensively manufactured for diverse and specific applications. Common construction materials include aluminum/magnesium, steel, and wood. Because these trucks are so inexpensive, it makes sense to design them for specific material handling functions. In this way, it is possible to increase the cube utilization within the truck for material handling optimization. Aluminum or magnesium trucks generally carry 300-500 pounds of material, while steel or wooden trucks can be used to carry approximately 1000

pounds to 2000 pounds, respectively. The trucks range in weight from as little as 20 pounds for aluminum trucks to as much as 125 pounds for wooden trucks.

Non-powered hand pallet trucks

These trucks are designed to carry unit loads on pallets from one location to another, generally in indoor settings. Because unit loads can be quite heavy, the distances transported using this type of equipment is generally short. In many settings, hand pallet trucks are used to supplement motorized truck fleets. They are extremely efficient for transporting unit loads short distances when high lifting is not required. They can be used to position materials very precisely. Generally speaking, non-powered hand trucks cannot be used to lift more than 8,000-10,000 pounds and cannot lift a unit load to a height more than 8 inches. For heavy duty applications, steel wheels are required while lighter duty applications require only nylon or polyurethane construction. These trucks can range in weight from 200 to 400 pounds.

Pallet Trucks

The full featured ergonomic pallet truck is an economical way for one person to move heavy pallet loads without the use of a fork truck. Proven ergonomic design has been tested for providing years of reliable usage.

This pallet truck includes two articulating steering wheels and two front load rollers. Ergonomic design requires only 75 lbs. of pulling force when fully loaded. Steering wheels include bearing dust covers for added life. Nose wheels are located on the front edge of each fork to assist in clean pallet entrance and exit. Reinforced triple-formed steel forks provide twice the strength of standard single-formed forks.

Equipped with internally mounted solid steel adjustable push rods. Spring loaded loop handle automatically returns to vertical position when not in use. Chrome-plated hydraulic pump piston for long seal life.

Powered pallet trucks

Hand pallet trucks, with capacities up to a max of 2 tonnes, are probably the most commonly used trucks for the horizontal movement of pallets. It is not uncommon to see these trucks lifted on to the back of the vehicle for positioning pallets during loading and unloading. However, for frequent movements, and where there are inclines to be negotiated, battery –powered trucks are preferable in terms of operator effort and safety, and these can be pedestrian – or rider- controlled.



Pallet truck and counter scale pallet truck - (www.forklifttruck.com)

Counter balanced fork-lift trucks

Counterbalanced fork-lift trucks carry the payload forward of the front wheels, so there is always a turning moment lending to tip forward. To balance this, a counter balance weight is built into the rear of the machine-hence the name. These machines capacity varies from 1000kgs to 45,000 kgs with a lift height of up to 6/7 metres.



Counter balanced truck - (www.forklifttruck.com)

Reach trucks

Reach trucks are designed to be smaller and lighter than counter-balanced trucks and to operate in a smaller area. Its capacity varies from 1000kgs to 3,500 kgs with a max fork-lift up to about 11 metres. This is achieved by having a mast that can move forward or back in channels in the outrigger truck legs. Then picking up or setting down a load, the truck is turned through 90 degrees to face the load location; the mast reaches forward, places or retrieves the load, and is retracted back into the area enclosed by the wheels.



Reach truck - (www.forklifttruck.com)

Double reach trucks

A conventional reach truck can only reach one pallet deep into racking. For accessing double deep racking a double reach truck has to be used, which uses a pantograph mechanism to achieve the additional reach. Double reach can also be achieved on some lighter trucks by the use of telescopic forks. Double reach machines are also used for side-loading pallets on to road vehicles, working only from one side of the vehicle.



Double reach truck - (www.forklifttruck.com)

Four-directional reach trucks

On a conventional reach truck, the front wheels always face forward, and steering is from the rear wheels. The 4D truck has an additional option of being able to turn the front wheels through 90 degrees and lock them in this mode. This effectively converts the truck into a side loader and is especially useful in stores and warehouses where part of the stock range consists of long loads. For access to say cantilever storage, very wide aisles would be necessary if this option were not available.



Four-directional reach trucks - (www.forklifttruck.com)

Stacker trucks

These are fairly light weighted trucks with max capacities up to 2000 kgs. There are pedestrian, stand-on and ride-on versions. Pallets are put into or taken out of storage racking by the truck legs being driven into the space either under the bottom pallet beam supported). When picking up pallets at floor level, the forks have to be lowered right down on to the outrigger legs, so perimeter-based pallets cannot be used, since they would be sprung apart as soon as the forks were raised. This problem is overcome if the lowest pallets are located on low beams with sufficient space underneath to accommodate the outrigger. These trucks are usually limited to about a 6 metre lift, but they can operate in 90- degree turning aisles of only 2 metres or less.

High rack stacker trucks-very narrow aisle

These trucks typically with lift capacities up to 2 tonnes and lifting to 12/13 metres, are equipped with mechanisms on the mast that can set down or pick up pallets from the racking without the truck having to turn in the aisle. Consequently they can operate in aisles of 1.8 metres or less. The very narrow aisles and high lifts give good space utilization, but also necessitate very flat floors, which are expensive, to minimize the risk of collision between load and racking when manoeuvring loads. It is also necessary to have a guidance system to keep the trucks centrally positioned in the aisles.



High rack stacker trucks - (www.forklifttruck.com)

Order picking trucks

There is a range of manual and powered trucks designed specifically for order picking operations. These range from trolleys, such as roll cage pallets, to ground-level pedestrian trucks such as long fork powered pallet trucks, up to multi-level trucks in which the operator is raised for high-level picking.



Order picking truck -(www.forklifttruck.com)

Conveyors for unit load handling

Conveyor systems are used for moving material between fixed points, for holding material as short-term buffer, for sortation and for process industry applications such as separation, grading and cooling.

The general characteristics of the conveyor systems are:

- High through-put with few operators and low power requirement;
- Suitable for fixed routes, and floor surfaces are not critical as they are for fork trucks;
- Fast response and suitable for continuous or intermittent movements;
- Can utilize very sophisticated movement control.

Conveyor systems now find very wide application in both conventional and automated warehousing.

The less positive aspects of conveyor systems include:

- High capital cost;
- Can obstruct working areas and access;
- Inflexibility for future change;
- Hence very careful system design required including safety features.

The handling of products is a key to warehouse productivity for several important reasons.

1. The relative number of labour hours required to perform material handling creates a vulnerability to any reduction in the output rate per labour hour. Warehousing is typically more sensitive to labour productivity than manufacturing since material handling is highly labour-intensive.
2. The nature of warehouse material handling is limited in terms of direct benefits gained by improved information technology. While computerization has introduced new technologies and capabilities, the preponderance of material handling requires significant manual input.

Material handling in the logistics system is concentrated in and around the warehouse facility. A basic difference exists in the handling of bulk materials and master cartons. Bulk handling is a situation where protective packaging at the master carton level is unnecessary. Specialized handling equipment is required for bulk loading, such as for solids, fluids, or gaseous materials.

Over the years a variety of guidelines have been suggested to assist management in the design of material handling systems. These are representative:

1. Equipment for handling and storage should be as standardized as possible.
2. When in motion, the system should be designed to provide maximum continuous product flow.
3. Investment should be in handling rather than stationary equipment.
4. Handling equipment should be utilized to the maximum extent possible.
5. In handling equipment selection, the ratio of deadweight to payload should be minimized.
6. Wherever practical, gravity flow should be incorporated in system design.

The factors to be considered when deciding on the appropriate type of handling system for a particular application include:

- Types of load being handled including the unit load characteristics;
- Quantity of material being handled;
- Frequency of movement;
- Distances to be travelled, horizontal and vertical;
- Numbers and locations of pick-up and drop points;
- Adjacent activities;
- Nature of terrain;
- Flexibility required.

The principles governing the design and use of handling systems include:

1. Control of position and movement;
2. Elimination of unnecessary movement and minimization of the necessary movement;
3. Selection of the most appropriate handling method to meet the system requirements;
4. Provision of adequate handling capacity;
5. Integration of handling with the storage and other adjacent operations;
6. Thorough and effective operator training;
7. Effective equipment maintenance for operational availability and safety;
8. Safe methods of handling and working practices.

Handling system are classified as

- mechanized,
- semi automated,
- automated, and

- Information- driven.

A combination of labour and handling equipment is utilized in mechanized systems to facilitate receiving, processing, and/or shipping. Generally, labour constitutes a high percentage of overall cost in mechanized handling. Automated systems, in contrast, attempt to minimize labour as much as practical by substituting capital investment in equipment. An automated handling system may be applied to any of the basic handling requirements depending on the situation. When selected handling requirements are performed using automated equipment and the reminder of the handling is completed on a mechanized basis, the system is referred to as semi automated. An Information – directed system uses computers to maximize control over mechanized handling equipment. Mechanized handling systems are the most common. However, the use of semi automated and automated systems are rapidly increasing. As noted earlier, one factor contributing to low logistical productivity is that information-directed handling has yet to achieve its full potential.

General Considerations

	Conveyors	Cranes and hoists	Industrial trucks
General Applications	Moving uniform loads continuously from point over fixed paths where primary function is transporting	Moving varying loads intermittently to any point within a fixed area.	Moving mixed or uniform loads intermittently over various path with suitable surfaces where primary function is maneuvering
Material Volume	High	Low, Medium	Low, Medium, relatively high
Type	Individual item, unit load, bulk	Individual item, unit load,	Individual item, unit load, variety

		variety	
Shape	Regular,uniform,irregular	Irregular	Regular,uniform
Size	Uniform	Mixed,Variable	Mixed or uniform
Weight	Low,medium,heavy,uniform	Heavy	Medium Heavy
Move Distance	Any, relatively unlimited	Moderate, within area	Moderate,250-300ft
Rate, speed	Uniform, variable	Variable, irregular	Variable
Frequency	Continuous	Intermittent, irregular	Intermittent
Origin, destination	Fixed	May vary	May Vary
Area covered	Point to point	Confined to area within rails	Variable
Sequence	Fixed	May vary	May vary
Path	Mechanical fixed point to fixed point	May vary	May vary
Route	Fixed, area to area	Variable, no path	Variable, over defined path
Location	Indoors, outdoors	Indoors, outdoors	Indoors , Out doors
Cross Traffic	Problems in by-passing	Can be by- pass, no affect	Can be by-pass, maneuver, no affect
Primary function	Transport, process /store in move	Lift & carry, position	Stack, maneuver, carry, load, unload
% Transport in	Should be high	Should be low	Should be low
Operation			
Method Load Support	None, or in containers	Suspension, pallet, skid	From beneath: pallet, skid, container
Load/unload	Automatic , manual,	Manual , self,	Self, any point on

characteristics	designated points	any point	available package
Operator accompany load	No	May not, Usually does	Usually does, may be remote
Building characteristics Cost of floor space	Low medium	High	Medium, High
Clear height	If enough, conveyor can go over head	High	Low, medium, high
Floor load capacity	Depends on the type of conveyor and material	Depends on activity	Medium, high
Running Surfaces	Not applicable	Not applicable	Must be suitable
Aisles	Not applicable	Not applicable	Must be sufficient
Congested areas	Fair	Good	Poor

(<http://www.mhia.org/et/pdf/mhi/cicmhe/equpguid.pdf>)

AS/RS (Automated Storage & Retrieval Systems)

Introduction

This chapter will present an overview of some of the more sophisticated handling and storage systems to be found in warehousing applications. They include highly mechanized systems, automated systems with computers controlling the physical movement and storage of materials, and robotic applications. Such applications may be said to be at the technologically advanced end of the equipment and system spectrum in the context of warehousing, although some of the technology is well established and has been with us for many years.

‘High-tech’ installations are costly, involve 24-hour working, are somewhat inflexible and tend to require long payback periods. They should be based on some assurance of long-term demand for the products handled.

An example is the use of automated storage and retrieval systems (AS/RS) using computer-controlled driverless high lift stacker cranes in high bay warehouses, a concept that has been with us since the early 1960s. In this sort of application the computer is used to manage and control the physical movement of equipment, and hence of the materials being handled and stored. Many of the earlier stacker cranes were operator-controlled, but the facility for on-board operation is now more usually for maintenance purposes only.

During the last 10 to 15 years the pace of technological development and application has increased considerably. This has gone hand in hand with, and been encouraged by, the growth in information technology, and has been motivated by the increasingly tight requirements for accurate and timely customer service, and for inventory and cost

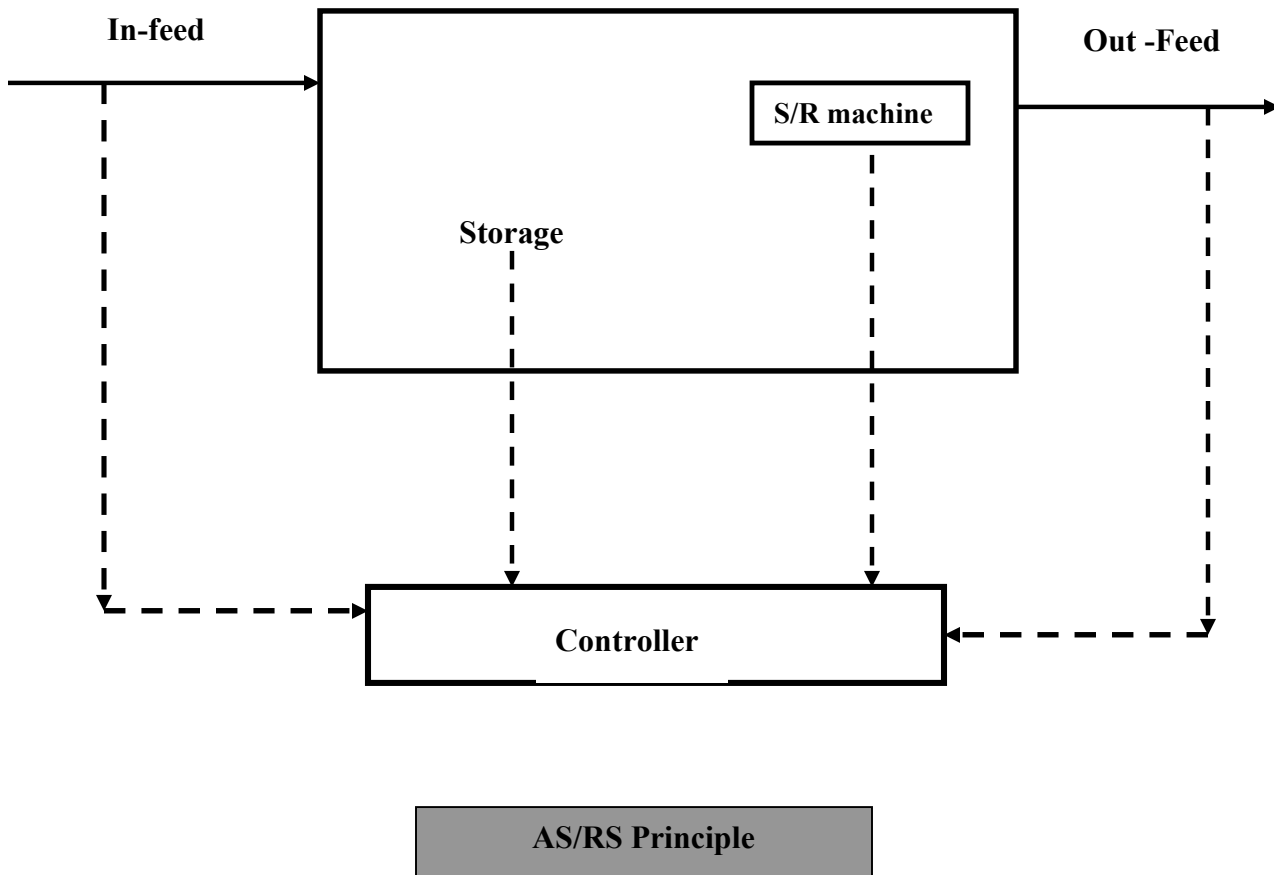
reduction. However, there are still many warehousing applications that do not make use of advanced technology, and the authors' view is that high-tech solutions are not always the answer to every handling or storage problem. Systems should be designed that best meet the overall system requirements, and in some cases that will be a 'low-tech' solution. One example of this was the building of a new clothing warehouse that had to be able to meet peak seasonal sales of up to three times the volumes experienced at other times of year. In this case the flexibility of a labour-intensive solution, in which the company could 'throw people at the problem' was seen as a major requirement for meeting seasonality and peak sales volumes. An automated solution would have been underutilized for much of the time.

AS/RS Systems for Unit Loads

The basic components of an AS/RS system are:

- ✓ Storage medium, eg pallet racking, or shelving for small-item tote bins;
- ✓ Storage and retrieval machines that operate in the storage medium;
- ✓ In-feed and out-feed systems, eg Forklift trucks, conveyors, AGVs
- ✓ Controlling computer.

The controlling computer monitors the status of all the components of the system and, based on the warehouse stock and movement requirements, plans the work to be carried out within the system and instructs the equipment accordingly



A typical installation could consist of high bay pallet racking, with stacker cranes operating in the racking aisles to put pallets away to stock and to retrieve them as required. Note that there are single deep and double deep stacker cranes, enabling the use of single or deep pallet racking on each side of each aisle. Installation heights of 45 meters or more can be achieved, and typical operating aisles for standard pallets can be about 1.5 meters. The computer would control the incoming and outgoing material flows, monitor the status of the pallet racking (what stock is located in each location and which locations are empty), and control the crane movements. Because of the generally tight clearances in such installations and to prevent possible jams in the racking, a strict profile check for incoming pallets is adopted to ensure that loads have not slipped on the pallets during transit, and that packaging material has not

come loose. Pallets outside the dimensional specification are rejected, and have to be rectified before being accepted into the system.

A stacker crane consists of a vertical mast or pair of masts supporting a unit load handling mechanism, which can be raised or lowered. The crane travels on floor-mounted rails running the length of each aisle, and is guided by an overhead rail. The unit load mechanism can pick up and put away pallets from and to either side of the racking aisle. Cranes can be designed for accessing pallets in single deep and double deep racking.

The amount of storage racking required depends on the designed stock-holding capacity of the installation. The overall rack dimensions are then determined by the height of building (allowed by the local planning authority), and by the lift and travel characteristics of the cranes. This then determines the number the number of racking rows required and the number of crane aisles.

The number of cranes required is determined by the total amount of a pallet movement that has to be carried out in a given period of time. If the number of cranes is significantly less than the number of aisles in the racking, a transfer facility can be incorporated into the design to enable the computer to move cranes between aisles as required. This usually consists of a transverse aisle at one end of the tracking, equipped with one or more transfers cars on to which the cranes can be driven and moved between aisles. If the number of cranes required is close to the number of aisles in the racking, it is probably better to have one dedicated crane in each aisle.

Design of AS/RS Systems:

The highly automated AS/RS has a simple design. A pallet conveyor system transports the heavy unit loads that interface with the AS/RS. Dual induction assures that pallets of product are inducted quickly and easily. A scan clearance tunnel checks for overhanging loads. Product is tracked from receiving to shipping by a “small system”

that tracks it from manufacturing and other sites. Software and controls provide information on inventory status, which assist in production planning and customer shipping schedules.

The pallets of product are stored by one of the six AS/RS, without operator intervention. Reduced handling translates into increased productivity and efficiency.

A unique feature of the AS/RS is its ability to interface with three different pallet types on rack load beams in both single and double deep configurations. As product is needed the pallets are retrieved. The AS/RS eliminates fork lift traffic in picking and transportation.

Pallet loads are transported by the heavy unit load conveyor system to order picking stations. An ergonomic conveyor lift is used to transfer the load. These lifts make picking easy by positioning the pallet loads at optimal working height.

Once the order is complete, it is dispatched to shipping by an automated rail guided transfer car. Pallets with remaining products are returned to the AS/RS automatically by the pallet transport system. Empty pallets are stacked and returned to production.

There are various applications of this principle of automated storage. They include:

- Small –item storage using ‘mini’ crane installations
- Long load storage of metal bar and tubing using cantilever racking-often in support of manufacturing operations.
- Paper reel handling using over head traveling cranes fitted with vacuum lifting heads, moving the reels into and out of vertical stack storage.

It should be noted that the term ‘automated warehouse’ is frequently used to describe installations that in reality are only partially automated. The handling of whole pallets into and out of racking may indeed be automated, but the order picking of cases from those pallets is in many applications still carried out manually. However, such applications will

always be supported by a good information and communication system, using such techniques as bar-coding and /or radio data communication.

A frequently used term in automated warehousing is 'high bay warehouse'. Generally this refers to a crane-accessed AS/RS system, and there are cranes designed to lift in excess of 40 meters high. Other terms associated with this sort of installation include 'roof on rack' and 'clad rack'. These both refer to the specific building technique in which the walls and roof are supported by the racking steel work, so avoiding the need for a separate enclosing building. This reduces the cost of building. There can also be tax implications according to whether the building is classified as a fixed asset or as 'plant'.

The major benefits of AS/RS Systems:

- Cut order fulfillment time in half while servicing manufacturing operations
- Reduce operations costs
- Maximize utilization of floor space
- Increase inventory accuracy
- No restocking errors
- Fast and accurate service

Types of conveyors**1. Fixed Path Conveying**

Fixed path conveyances are advantages for periodic and continuous transport of material between locations in warehouses and factories. They are also used to accumulate goods, store packages, change elevations, and provide a continuous work surface on which progressive assembly or processing can be performed.

Conveying systems Planning Criteria

1. Product size and weight (or container characteristics if used).
2. Distance
3. Control requirements.
4. Flow Rates.
5. Obstructions and facility limitations.
6. Human factors, including noise
7. Environment.

2. Gravity Conveyors

These conveyors are the simplest and usually least expensive. They are useful where material is moved for short distances and movement requirements are simple. Three common types are chutes, skate wheels, and rollers. They are often used in conjunction with powered systems. Pros and Cons are listed below

Advantages of Gravity Conveyors

1. Excellent for elevation drops.
2. Low initial and operating cost.
3. Quieter operation than powered conveyors.
4. Low maintenance
5. Low profile.
6. Easier to manually move products.
7. Unlimited configurations allow use for wide range of product weight.

Disadvantages of Gravity Conveyors

1. Less control of products on long runs, including failure to move once stopped.

2. Impractical for fragile products that are damaged by bumping or crashing.
3. Singulation and non-contact difficult.
4. Tend to increase the work in progress.
5. High pitch requirements.
6. May require manual assistance.

3. Horizontal powered conveyors.

These are used to move material over moderate to long distances.

Live Roller

This type of conveyor is used for a variety of applications, loads, and environments, but they are typically used for 30-50 lb.ft loads in warehouses. They can provide brief periods of product accumulation or dwell points. Live rollers can handle up to 10,000 lbs and can carry irregular shaped containers. Live rollers are classified by their drive method, listed below. Some disadvantages are:

Live rollers are classified by their drive method, listed below some disadvantages are:

1. Higher cost due to construction materials.
2. Product slippage on rollers requires frequent tracking update and diverter timing.
3. Products cannot negotiate inclines over 7 degrees without manual assistance.
4. Power surges when accumulating on driving rollers; disrupting product spacing.

4. Live Roller Accumulation Conveyors.

These conveyors are used to regulate the flow of products into downstream operations by providing a temporary buffer for excess products. Selection criteria depend on specific applications. Proper product alignment is required when using accumulation conveyors. Various releases are available, depending on conveyor speed. Three types of powered accumulation conveyors

- Zero-pressure .The line pressure (horizontal pressure between products) is eliminated.
- Non-Contact. Products are always separated from each other.

5. Slider Bed/Roller Bed Conveyors

The slider bed consists of a moving belt operated across a steel support bed. The roller bed is a belt supported by rollers. The slider bed is the least expensive powered conveyor, but handles less loading than the roller bed. Roller beds require more power than live rollers. Belt conveyors offer stable support, are used for heavy loads, and can be operated at high speeds. The belt conveyors maintain product spacing to allow excellent material racking. These conveyors are also used for inclines and declines of up to 30 degrees.

Belt conveyors are not used to accumulate products, but they can start and stop and they can be used to meter products at the exist of an accumulator conveyor.

6. Roller Curves and belt Turn Conveyors

Curves and turns are used to change the direction of material flow. Roller curves are less expensive than belt curves and they are the most common. They can be self powered or slave driven. Belt curves are used to maintain product orientation and spacing. The flat surface also allows handling of smaller, irregular sized products.

7. Sortation Conveyors

Sortation conveyors are used to identify packages, present packages to sortation equipment, or sort packages to multiple locations.

8. Powered Overhead Conveyors

Powered overhead conveyors are used when system flexibility is desired or floor space is congested because material flow paths are easily established and altered and obstructions are minimized, enhancing freedom of movement. Additionally, drivers and other equipment are offered some protection from the environment on the floor.

9. Vertical Conveyors

Vertical conveyors are used to lift or lower heavy loads between various levels in intermittent-flow operations and where horizontal space is limited. Of the two vertical types, the reciprocating is simpler, but the continuous supports a higher flow rate.

CHAPTER - 13

Bar coding Technology & Applications in Logistics Industry

Introduction

Efficiently run businesses require many operations to flow seamlessly and without hinderance. Automatic Identification or "bar codes", as the industry is more often referred to, makes these steps more efficient and accurate. A bar code does not change how a business operates, but it makes procedures faster and more accurate, providing useful management information in a timely manner. Bar codes can be employed in virtually all organizations and all professions to increase the productivity, efficiency and accuracy of specific business processes.

What is a Bar Code?



A bar code is simply a set of symbols used to represent alpha-numeric information. Basically, instead of seeing the number "1", or the letter "A", you would see a series of bars, both fat and thin, used to represent that number.

So, why replace the alpha-numeric characters with a bar code in the first place, you might ask. Humans can easily determine that a strange combinations of lines and curves and dots are put together to form a letter or number, but computers aren't as quick in deciphering such information. Even though Optical Character Recognition has come a long way in recent years, it's much quicker and much more accurate for a mechanical device to decode a series of black and white lines than it is to read human text.

A number of bar code standards have been developed and refined over the years into accepted languages called symbologies. We would use different symbologies for different application in the same way that we would use a bold or italic font to emphasize a particular line of text in a report. Different symbologies or "bar code fonts" are used for different applications. By having standardized symbologies, we ensure that when you print a bar code, I will be able to scan and decode it with my equipment and you will be able to scan and decode my bar codes—as long as we both use the same code and are within the specifications dictated by the barcode standards.

Bar code symbologies come in two basic varieties. They can be either linear or two dimensional in their configuration. A linear bar code symbology consists of a single row of dark lines and white spaces of varying but specified width and height, as indicated by the example below.



LINEAR

Similarly, a 2-Dimensional symbology can be configured into a stacked or matrix format. Two dimensional bar codes are special rectangular codes which 'stack'

information in a manner allowing for more information storage in a smaller amount of space.

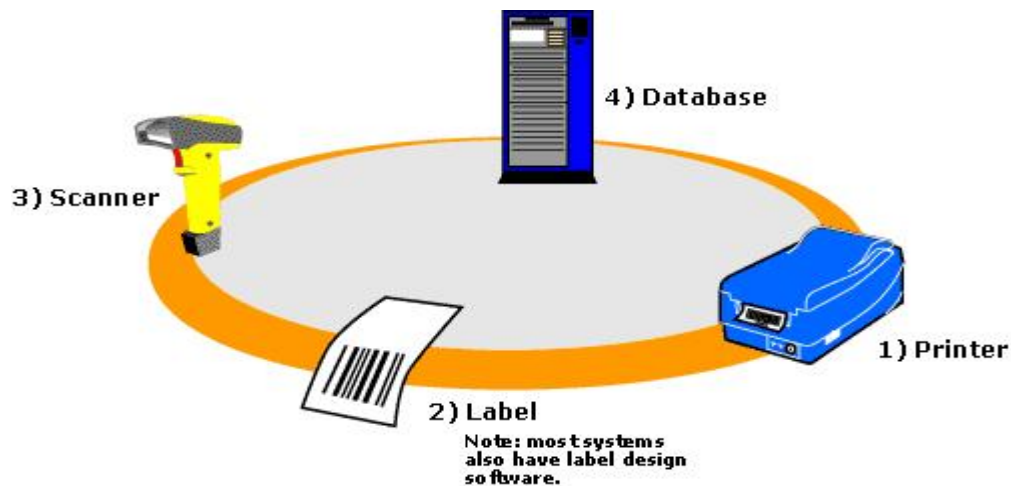


2-D SYMBOLOGY

The amount of data that can be encoded in a linear barcode symbology is more limited than that of a 2-D bar code symbology. A one inch 2-D matrix symbology, for example, can encode thousands of characters of data, whereas a comparable linear bar code would have to be several feet long to hold the same amount of information.

Components of Bar coding

Bar code systems come in many different sizes and shapes. The complexity of system required is determined by the application. A basic scanning system is fundamentally broken down into the following four components:



Component 1-The Bar Code Printer

The bar code printer provides the first component part in a bar code system. A variety of technologies and methods exist to print a bar code label. You can use laser printers and pre-set templates (often included in label design software such as Wasp Labeler

or Zebra Bar One software) to print your bar code labels. They are usually printed onto Avery stock. More commonly, labels are printed using bar code label printers such as those made by Intermec, Datamax, or Zebra. These printers print labels much faster and are of higher quality than those printed using a conventional laser printer.

Component2-TheBarCodeLabel

As mentioned above, you need the bar code printer to print the bar code labels. In addition, you need some software application that can design your labels. These are the same labels that you will then attach to a box or an asset for tracking. An item label can contain any combination of text, graphic or bar code information. Many label packages such as Wasp Labeler or Zebra Bar One, have pre-made templates that can easily start you on your way to designing your label. In addition, they have compliance label templates for specific industry labels such as the automobile industry.

Component3-ScanningEquipmentforDataCollection

The data collection phase occurs through the use of scanners that instantly and accurately read, capture and decipher the information contained in the bar code label. Scanners read information much faster and more reliably than humans can write or type. Thus, significantly reducing the rate or likelihood of error. There are two different types of scanners: contact and non-contact. Contact scanners required physical contact to scan as opposed to non-contact scanners which can be several inches to several feet away. Of these two types of scanners, there is also one other major attribute; they are either decoded or non-decoded. Decoded scanners have built in hardware decoders that interpret the meaning of a bar code before sending the data to the computer. Undecoded scanners simply have light sources that capture the encrypted data and sends them to a decoder of some sort. Decoders are either in-line hardware units or software decoders that run on your computer. As you may have guessed, decoded units are usually more expensive than their undecoded counterparts. They do have the distinct advantage of only having one component to worry about if something breaks down instead of trouble shooting many components to find out why your bar codes aren't reading properly.

Component4–Capturing the Data to an External Database

The final component to establishing a simple bar code system is the database. Just because you've created and scanned bar codes successfully doesn't mean you've completed the loop to creating a complete and effective bar code system. To be able to effectively use the codes you've created and scanned, you need a database of some type to relay and update information. Many bar codes can be tied to item numbers for example. These item numbers can then, in turn, be linked to information about the item, such as product description, price, inventory quantity, accounting, etc. For example, let's say you have widget A, with a corresponding bar code that has the value of 1234. When you sell widget A, you scan the bar code. This, in turn, causes a chain reaction that tells your database that you: have one less widget A in stock, that you should charge \$.20 for widget A, that this information should be passed onto accounting, that the product needs to be shipped only through UPS ground, etc. All of these actions were caused by scanning the bar code representing Widget A. You get the gist to the significance of having an external database.

There are many other configurations, but this is the fundamental building block for bar coding.

Why Should You Consider Bar Coding?

Implementing a proper bar code system offers tremendous advantages to a company. The most compelling advantages of bar coding and automatic data collection are:

Accuracy

Bar coding increases accuracy by reducing the likelihood of human errors from manual entry or miscommunication from misread or mislabeled items.

Ease-of-Use

Bar codes are easy-to-use provided the appropriate hardware and software aspects are in place to maximize the process of automatic data collection. Obviously, pulling a trigger to enter in inventory is going to take much less effort and brain drain than it would to accurately account for all the inventory by hand.

Uniform Data Collection

Diverse compliance standards and standardized bar code symbologies ensure that bar code information is captured and relayed in a fashion that is universally understood and accepted.

Timely Feedback

Bar coding promotes timely feedback in that data is captured in real-time as it occurs enabling decisions to be made from current information.

Improved Productivity

Bar codes improve many activities that streamline workflows throughout a business. Remember when cashiers used to enter the price of your groceries by hand?

Increased Profitability

The increased efficiencies that bar coding promotes enables companies to save costs and substantially improve their bottom line.

Benefits of Bar-coding

Many people think of bar coding strictly as a technology. A broader way of looking at bar coding is viewing it as a tool for managing information. Bar codes enable quick, accurate data entry. Having accurate data available enables managers to make decisions based on valid information. For example, with a manual system you often must make an educated guess on inventory levels and when to reorder products. On the other hand, the accuracy of bar code scanning provides upto- the-minute information about inventory levels, including the value of inventory investment. This information can help you maintain lower inventory levels and improve cash flow, which is invaluable to your hospital. The most compelling advantages of bar coding and automatic data collection are:

- **Accuracy:** Bar coding increases accuracy by reducing the likelihood of human errors from manual entry.

- **Ease of use:** Bar codes are easy to use as long as the appropriate hardware and software components are in place to maximize the process of automatic data collection.
- **Timely feedback:** Bar coding promotes timely feedback of data captured in real time, enabling decisions to be made from current information.
- **Improved productivity:** Bar codes improve productivity in that many manual activities and tasks become automated, enabling resources to be utilized in other ways to increase efficiencies.
- Bar code technology can be translated into three primary functions: **tracking, inventory management, and validation** .Whether you use one function or a combination of functions, the benefits in cost savings, improved productivity, and quality can be substantial.

Tracking

Anything that can be identified with numbers (or numbers and letters) can be tracked using bar code technology. Materials management, central services, medical records, radiology, pharmacy, and laboratory are areas where bar codes are commonly found in hospitals. However, applications continue to expand to nearly every area to help track cost per procedure, products used by clinicians, and total patient costs. In addition to assuring greater accuracy, bar codes help speed the process of recording where and what an item is, or what service is provided. Bar codes can be used to track a product through out the supply chain and clinical workflow. They may be used to track a supply to a particular patient and also can identify the clinician who used it with the patient. Bar coded numbers also can be used to track a particular item back to the manufacturer. For example, if a nurse discovers a defective supply item, bar coding can help track the item back through materials management and purchasing to the distributor and/or original manufacturer so the hospital can obtain a refund. Although it is possible to do the same thing manually, the amount of time involved would make the

process too cumbersome. Often, the hospital will bear the cost of an unusable item rather than trying to investigate and complete all the paperwork.

Inventory management

Maintaining accurate inventory is a very complex process of knowing what you have, how much of it you have, who has it, where it is, how much it is worth, and when to reorder it. Every hospital maintains centralized and decentralized inventories that could include medical/surgical products, office supplies, linens, pharmaceutical products, X-ray film, cleaning supplies, laboratory products, and more. Bar coding helps you manage these inventories wherever they are located, so that the right materials are available when and where you need them. Using a bar code also can help you monitor usage patterns throughout your hospital. In one hospital, the materials management department began collaborating with nurses to reduce inventory at nursing stations. Because the materials management department had accurate, documented information, they could create more realistic inventory levels. For example, if a particular unit used only eight of a certain item a day, but was keeping 17 of those items on the unit, the two groups worked together to find a satisfactory lower inventory level. In addition to the savings in inventory costs, this process strengthened communication and trust between materials management and nursing. Scanning the bar code on a product can speed the reorder process. Some hospitals use systems designed to automatically reorder products when they reach a specified inventory level.

Validation

The validating function of bar coding can be an especially effective method of ensuring quality in a Health care setting. Validation assures that an action has taken place or that the item you want is on hand. The ability to validate an action by a bar code scan helps reduce errors and waste, provides a management check on productivity, and helps construct the necessary documentation to meet requirements of the Joint Commission on Accreditation of Healthcare Organizations (JCAHO) and insurance companies. The most important validating function is to verify that the patient being

treated is, in fact, the right patient and that the treatment that is about to occur is appropriate. Nurses can scan a bar code to confirm that the item they are about to use with a patient is the item ordered by the doctor. They also can validate that they have used the item with the right patient. Nurses do this by scanning the bar code on the employee identification badge, the bar code on the patient wristband, and the bar code on the item. This type of validation typically requires that decision support be in place to accomplish the checking function.

Common Bar Code Applications

In retail applications, labels adhered or attached to a product or item of clothing contain barcodes which are read by a scanner during checkout and interpreted by a computer. The computer recognizes the barcode's data bit reference and is able to link the item to its sales price and description contained in the store's mainframe database. This product information is reflected, not only, on your sales receipt, but is automatically linked to the store's inventory tracking system which knows to deduct the quantity of the item purchased from the store's current level of inventory. This entire process occurs in a matter of seconds with only minimal data entry required by the checkout person in the form of quantity purchased – e.g. one or more.

Similarly, in a package delivery scenario, e.g. common carriers such as UPS® or FedEx®, the barcode label enables the package to be tracked as it passes through diverse sorting hubs en route to its ultimate destination. Throughout the package's journey, each sorting hub scans the package to register its receipt before passing it onward. Thus, if the package's arrival is ever delayed or misplaced, it can usually be tracked by its bar code tracking number to the exact point in the process where it may have stalled.

In addition to the retail and packaging industry, barcode data collection is used in a variety of industries, including but not limited to manufacturing, healthcare and automotive. Generally any industry or company can utilize bar coding to track and improve their current processes and operations. Some of the most common bar code applications referenced in the industry are:

Shipping & Receiving Compliance Labeling

Compliance labels utilize bar codes to facilitate and expedite shipping and receiving process functions between one's suppliers and/or vendors. As a purchase order is received, the operator scans the bar code label and keys in the quantity that has been received into a hand-held portable data terminal which uploads this information to the computer mainframe. The mainframe can then point out product shortages that are double-checked on the spot rather than after an item has been moved or partially used. Similarly, as items are loaded in preparation for shipping, they are scanned enabling shortages or misloads to be detected immediately. As items are stored into inventory, the computer, thus, immediately registers the stock quantities as being available for picking to satisfy an upcoming order.

NOTE: Compliance label specifications vary depending on the customer. Any shipment not in accordance with a client's specified compliance labeling requirement may be rejected and can result in a monetary fine, depending on the frequency and extent of the occurrence.

Inventory Control

Bar codes are frequently used for inventory control to track an item's location and turnaround. When an item is either removed or entered into inventory its Product Description, Lot #, and Location are scanned from the shelf label by a portable data entry terminal which communicates this information back to the company's computer mainframe via radio frequency. The quantity of product removed from inventory is entered separately (by the user) into the portable data terminal for relay to the mainframe so that the current inventory level is also registered within the mainframe. Product re-orders points within the computer mainframe are set-up to recognize when an item needs to be replenished via the release of a Purchase Order to a given supplier.

Work-in-Process

Work-in-process labeling is frequently used in manufacturing facilities to monitor each phase in a manufacturing process to ensure consistent quality and output. With on-line or portable readers, scanning of a routing sheet with bar codes on them as parts or sub-assemblies are completed enables work-in-process costs and manufacturing progress to be tracked.

Labor or Assembly Tracking

Similar to work-in-process, bar codes for labor tracking of a manufacturing process ensure the consistent quality and output of a job. Consider the following example: In a custom assembly, a terminal leads the operator in what to assemble. As the operator scans each part or sub-assembly added, the computer can monitor it for correct specifications. Should a manufactured part be found faulty, it can then be tracked back to the exact point and/or person responsible for the error.

Time and Attendance

Time and attendance is yet another popular application for bar codes. An employee badge with a bar code can be read into a computer terminal at clock-in and clock-out stations to provide attendance data to a computerized payroll program.

Asset-Tracking

Bar codes can help companies to track their assets by way of equipment or hardware that they may temporarily loan out to someone. A bar code placed on a rental video, for example, is scanned at checkout along with the borrower's ID card enabling the item to be tracked while it is on loan.

Warehouse Picking

Involves a computer that downloads a list of items to a portable data terminal that instructs a warehouse worker to pick those items associated with a specific order. As locations are reached or items are picked, the bar codes are scanned and the terminal compares what was scanned to ensure that the right location or item is being picked.

After picking the order, the worker goes back to the terminal to upload the data to the computer mainframe and to receive his next order of instructions for picking.

CHAPTER - 14

RFID Technology & Applications

Introduction

Radio Frequency Identification (RFID) is a fast and reliable means of automatically identifying and logging just about anything, including retail items, vehicles, documents, people, components and works of art. Because it makes use of radio waves, there is no need for “line of sight” reading of information, which is one of the limitations associated with barcode systems. It means RFID tags can be embedded in packaging or, in some cases, in the goods themselves.

Information from an RFID system – the “data capture” element of an IT system – is passed to management information systems that are used, for instance, to control stock levels and provide details of who is currently in possession of what asset. Apart from its automatic identification and data capture capabilities, RFID can also provide the electronic article surveillance (EAS) function – a case of single technology taking the place of two.

A tiny chip connected to an antenna – typically a few centimeters square in total – sends information when requested to a reader. By means of anti-collision techniques, many tags can be read practically simultaneously, representing an enormous timesaving over barcode reading, which requires operators to find the right position for the reading of each barcode individually.

An RFID tag can work just like a barcode – in other words, it can hold a unique article number which works like a “licence plate”, calling the information relating to that number from a separate database. But because it can contain a relatively large amount of digital data, the RFID tag can hold source information itself, as opposed to a mere “look-up” number, thus making it infinitely more useful for supply chain and many other applications.

In addition, RFID “readers” in a read-write system are also “writers”: that means information can be written to tags at any point in, for instance, a supply chain, a security and access procedure or a maintenance operation, using a hand-held or fixed

reader. With a barcode system, the only way of changing information is to print a new barcode or alter information in the system's database.

The principle of RFID

An RFID architecture that leverages the auto ID center's current set of production-ready standards consists of the following building blocks:

- ✓ A passive RFID tag, which, when exposed to the electromagnetic waves of the RFID reader, broadcasts its electronic product code (EPC) information.
- ✓ An RFID Reader, which activates the tag and reads its response.
- ✓ The Air Interface, which can be specified using the Auto ID center standard or ISO 18006.
- ✓ The savant server, which has a real-time in memory database (REID), an event management services (EMS) and a task-management system (TMS) used to filter the stream of information from the reader to the next higher level.
- ✓ The Application server communicates with the savant server via a simple object Access Protocol (SOAP) interface that leverages secure socket layer (SSL) encryption to transport information over the Internet. The application server middle ware bridges the gap between the savant-based protocols (SOAP) and the (proprietary) protocols used by the business systems. RFID information can also be routed directly to the supply-chain execution systems, such as a TMS, WMS, and point of sale or Supply chain Event Management Environment. However, this puts additional load onto these systems and exposes them directly to the savant deployment strategy in the enterprise.

The RFID tag responds to the reader by broadcasting its EPC, which is a 96-bit code consisting of

- 8 bits of header information.
- 28bits identifying the organization that assigned the code
- 24 bits identifying the type of product.
- 36 bits representing serialization information for the product

RFID Challenges

RFID Better than Barcode?

As RFID technology reaches greater deployment levels, the cost of tags and readers will drop even further and RFID will become price competitive with conventional barcodes. However, RFID brings several key advantages to the table that will make it a relevant competitor to barcodes, even while the cost of a tag is higher than the cost of a printed barcode label.

- Barcode can be read only the line of sight; labels must be positioned to be directly visible to the barcode reader. RFID tags need to be within the RFID reader's radio reach (about ten feet).
- Barcodes cannot be read inside other containers, RFID tags can be read through most materials. Thus, the concept of a shipping container can be verified easily without the costly overhead of an "Open Box Inspection" and manual counts and comparisons with shipments manifests.
- Barcodes provide only limited amounts of information –even two-dimensional barcodes are limited in the amount of data they can carry. The Auto ID center's definition of a product information server (consisting of a distributed repository Infrastructure and naming services) allows us to tie unlimited amounts of dynamic information to each tag.
- Barcodes identify classes of products –RFID tags identify individual products. The Auto ID center concept aims at identifying and tracking individual product instances as they move through the supply chain, thus achieving greater granularity and better accuracy.
- The migration of supply chains from barcodes to RFID will require significant investments and will not happen overnight, RFID and barcodes will co exist – infact, they will co exist with human readable labels-for the foreseeable future.

Benefits of RFID**Labor Productivity**

Worker productivity levels will increase in the receiving area of the warehouse. Instead of manually scanning each inbound shipment and verifying it with the purchase order, the increased automation from the RFID technology permits employees to eliminate manual operations in the receiving function which will allow products to move to storage or the outbound dock faster. Other tasks that receiving can complete more efficiently with RFID are: 1) facilitating the return process of damaged or unsaleable goods; 2) improving quality control (on order integrity); 3) increasing put away rate; and, 4) minimizing errors in placement of shipments (cross dock or storage). Forklift drivers will also have an easier time putting away items in assigned and unassigned slot locations. There would be no need to scan an additional barcode on a pallet at the slot location. Furthermore, RFID technology would eliminate the need for physical inventory counts and reduce cycle counting. Moreover, employee's work location can be tracked through RFID technology revealing the amount of activity recorded. These studies will increase work productivity by providing employees with incentives to work more efficiently and effectively.

Inventory Reduction

By installing RFID technology into a warehouse, organizations reduce many of the challenges associated with inventories. RFID tags provide more visibility to the products so their location is more easily determined in the warehouse. This increased visibility reduces the likelihood of a stock-out occurring because of misplaced inventory or inaccurate inventory levels. Cycle service levels will also improve due to lower safety stock levels and the overall faster throughput of product at a warehouse. According to an inventory management report, RFID technology will reduce total system inventory by approximately 5%.

Facility/Equipment productivity

RFID technology allows more data to be processed faster through a WMS. The WMS uses the acquired information to improve the operations of the warehouse. If vehicles are scanned as they enter the inbound gates of the warehouse, dock utilization improves because the WMS can more effectively assign vehicles to unloading doors based on order priority. If the product is not needed right away, the WMS would assign the vehicle a position in the yard. RFID technology also removes the need to manually place bar coded items on conveyors in a specific orientation so that barcode readers can read them.

Other Benefits

There are several other benefits to the warehouse using RFID technology. Shrinkage, which is product stolen by employees along with misplaced items, will be reduced because the warehouse will have a better understanding of where the products are located and it will be more difficult to move products out of the warehouse without being detected. Forecast accuracy will also increase due to higher levels of visibility of product throughout the supply chain. This improvement will positively affect the overall efficiency and effectiveness of the warehouse in areas such as: 1) order cycle times; 2) safety stock levels; 3) fulfillment accuracy; and, 4) cycle service levels.

One of the most serious examples of misinformation about RFID in recent years has been the claim that it is generally more expensive than barcode systems. It's true that an individual tag is more expensive than an individual barcode. It's also true that RFID – currently, at least – is inappropriate for the tagging of low-cost items. However, the comparison needs to go much deeper than that. That is particularly so in supply chain applications where containers holding the goods and the dollies on which they stand have a distinct inventory value of their own. Consider this:

Tags are reusable and have very long lives, so in a supply chain operation where containers (often millions of them) are continually reused, there would be no need to re-label the containers, saving on manpower and other costs associated with label production and fixing.

Multiple tags (up to 100 or more) can be read practically simultaneously. Using latest breakthrough technology, the Multi Scanner and photograph the reading takes place on the move as the dollies supporting containers are pushed through the Multi Scanner portal, or gateway. The productivity gains over barcode reading are enormous.

An RFID system can track and trace the containers, dollies and other reusable equipment used in the transportation of the goods, as well as the goods themselves. This is highly significant for distribution / logistics companies with container inventories of several million pounds, who need to ensure that their assets are returned regularly. If 10 per cent of assets are lost in a year due to poor or non-existent trace ability by a distributor with £10 million worth of reusable containers, an RFID system could pay for itself in months on this basis alone.

RFID has been proven to be more efficient than barcode systems in terms of read failure rates, even though the speed of read is many times faster. RFID is also less prone to human errors.

In summary, RFID provides:

- Substantial productivity gains
- Elimination of re-labelling costs and effort.
- Greater accuracy
- Flexibility of data on the tag – e.g., goods and containers can be identified and
- tracked using the same tag
- Ability to write additional or replacement information to a tag at any stage in the supply chain.

All of this means that goods can be checked in and out much faster and **AT A LOWER OVERALL COST THAN THAT ACHIEVED BY EXISTING SYSTEMS**. For a comparison of costs associated with bar-coding and RFID systems in a typical supply chain situation, see RFID vs. Bar-coding on our Asset Tracking page.

Source: www.intellident.co.uk:

RFID's biggest advantage is being a non line-of-sight communication technology. Eliminating the need for line-of-sight communication allows products, cases and pallets to be automatically scanned in larger volumes and at higher speeds, allowing for greater improvements in efficiency. RFID solutions consist of four basic components: 1) Tags; 2) readers; 3) antenna; and 4) software. Each will be discussed briefly below.

Tags

RFID tag is a device that is placed onto, or in some cases into, the pallet or SKU.

Basically,

a tag is an electrical device that uses radio frequency antenna to communicate with the

RFID reader. Information is stored in the tags that describe the object

Tags can be differentiated as being active or passive. These can be seen in the pictures below. The active tags are self-powered whereas the passive tags use the signal from the RFID reader as the source of power. While the distinction between tags might seem minimal, the impact on their capability is significant in both read range and data storage. Active tags use a battery-powered transponder that emits a constant signal containing identification information. Active tags have the greatest range of all RFID tags, including search and read/write capability. Today, they have up to 128 Kbytes of storage space, but could hold more in the future. Passive tags have no battery, but instead rely on an antenna as the power source, drawing power from the reader's electromagnetic signal. Passive tags have a much more limited range (less than 2-3 yards), have limited storage space (as of now, 128 bytes, but could hold more in the future), and lack data manipulation capabilities.

Passive Tag



Active Tag



Readers

RFID tag readers are simply devices that scan the RFID tags. RFID tags have an antenna that transmits and receives information. The reader decodes and reads the information. The RFID reader converts the radio waves from the RFID tag into a form that can be passed along to an information system. The cost of the readers corresponds directly to the level of functionality needed. Readers that must scan multiple items, moving quickly on a high-speed conveyor or through a dock door are significantly more expensive than the basic hand held readers.

Fixed Reader



Mobile Reader



Antenna

RFID tag readers use an antenna to communicate to the RFID tag through the tag's antenna. Some readers have integral antenna while other can have various types and sizes of antenna fitted to them. The antenna is a critical component in the RFID system, as it has to be built for the coverage area. The antennas vary depending upon the facility location, size, area, and volume. Usually, an antenna operates in the 3-15 MHz range.

Software

Software and middleware are the most important pieces of an RFID solution. These packages are needed to make use of the information read by the reader to integrate the RFID technology with all the other systems operating in the warehouse: warehouse management systems (WMS), transportation management systems (TMS), event management systems (EMS), order management systems (OMS), and enterprise resource planning (ERP) systems. The ability to capture, store, rationalize, and integrate information captured by RFID technology, including product information, location, volume, and transactional data, allows organizations to more efficiently pick/pack, ship, route, track and distribute materials. This operational improvement can result in lower inventory levels and improved labor and equipment productivity. Integrating the information from RFID tags into an EMS or ERP system allows alerts and alarms to be sent when a certain set of conditions has occurred, e.g., inventory is running low or products have been idle too long. The information from RFID will also be useful when integrated with reporting software. Companies will be able to quickly target problem areas in their warehouse and identify areas of improved efficiency.

However, due to the lack of systems standards, there can be compatibility issues that arise in the software implementation process. Standards are currently being developed at EPC global, the main organization responsible for setting industry wide standards. Stand-alone, the RFID system is nothing more than data transmission. But through integration with other enterprise applications, the true value of the RFID system can be realized.

RFID IN Retailing Sector

Operating at razor thin margins in a highly competitive and largely undifferentiated market, top retailers are always on the look out for opportunities that have a positive impact on the bottom line. Retailers have engaged in several initiatives to operate at higher levels of efficiency. Extensive use of information technology for process automation, supply chain collaboration techniques like CPFR, VMI and efficient data exchange mechanisms like EDI and XML have all enabled leading retailer's wal-mart to run a tight-ship and gain competitive advantage. Within RFID inching up to the peak of inflated expectations in the hype cycle, this paper explores whether the added benefits from RFID provide reasonable justification for accelerated adoption by these enterprises.

RFID is an automatic identification and data capture (AIDC) technology which allows for non-contact reading to track and monitor physical objects. There is a tremendous interest in the application of RFID to the manufacturing /Retail supply chain, which has gained momentum primarily on the strength of the technological advances that are bringing down the costs of tags and readers and the efforts of the EPC Global Inc. in establishing industry standards. A key benefit of RFID technologies is *automatic identification* of individual objects coupled with *automatic data capture*. Automatic electronic identity contributes significantly to enhance **supply chain visibility**, and the automation brings in data capture and has a direct bearing on **operational efficiency** in labor intensive Retail Logistics.

Supply Chain Visibility

Physical tracking of merchandise today is a challenge with significant implications across the supply chain for Retailers. Visibility into the merchandise pipeline within the enterprise is extremely critical to ensure that an optimal level of inventory is maintained – not too much to lock in excess working capital, and not too less to cause stock-outs. Also, lack of visibility results in insufficient coordination between material flow and information flow often causing a magnification of demand variability in each level up in the supply chain – a phenomenon popularly known as the bullwhip effect. Companies rely on a variety of means for real-time data and process integration to alleviate this problem.

Operational Efficiency

A key element of cost in a retail enterprise is the area of Logistics Management – encompassing all activities that enable the movement of merchandise from vendor/manufacturer premises to the intended point of sale. About 25-30% of the supply chain costs can be attributed to labor costs in the process of distributing merchandise. Retailers extensively use software tools for warehouse management, yard management and transportation management. Industrial automation systems like conveyors, carousels, unit sorters enable enhanced operational efficiency within the distribution center. Business process innovations like multi-order picking, pick-to-light, use of voice and wireless technologies have all contributed significantly to higher productivity in warehouse operations.

Potential Benefits of RFID to Retail Enterprises

Falling prices of tags and readers and the rapid strides in the standards development process is making RFID technology an increasingly viable option for pallet and case level tagging. However, Retailers stand to gain most when individual items are tagged, with significant opportunities in enterprise inventory management and retail store operations. While the current tag costs rule out the economic viability of item/unit level tagging in most cases, there still could be a good business case in certain specific

merchandise categories and applications. Pallet and Case level tagging also has the potential to enhance operational efficiency for the Retailer. The likely return on investment from RFID tagging varies largely, and is an inverse function of the current level of process optimization. Typically, processes that employ *lower* levels of process automation tend to demonstrate *higher* returns. For example, the receiving and check-in process in warehouses as well as stores is a labor intensive and time consuming process. For a warehouse that currently employs minimal automation in the receiving process, one can expect **major** benefits by one-step receiving achieved using RFID tagging. On the other hand, the benefits would be much lesser if one-step receiving is already deployed using state of the art material handling equipment and data capture means.

What follows below is a quick look at the potential benefits from RFID in various functions in the Retail value chain, and an assessment of the added value over and above a process that employs the state-of-the-art automation.

Function	Benefits From RFID	Current State -of - the Art	Potential added value from RFID
	Enhanced in-stock merchandise position		
Replenishment Planning	Enhanced visibility and accuracy of data will enable planning	Near real-time visibility accomplished by intra-enterprise application	Moderate

	systems to make accurate projections. Reduced in stock inventory and increased inventory turns	integration	
Function	Benefits From RFID	Current State -of -the Art	Potential added value from RFID
	Real Time Routing		
Transportation	Visibility of merchandise in transit enables real-time changes in routing decisions.	Systems in place to provide visibility ,albeit at a higher level of granularity	Moderate
Function	Benefits From RFID	Current State -of -the Art	Potential added value from RFID
	Operational Efficiency		
Yard Management	Tags on trucks and trailers enable efficient tracking enhancing the reliability of yard management	Manual data entry	Moderate

	Better Utilization		
	Reduced times in loading and unloading enables higher asset productivity	Relatively less efficient	Major
Function	Benefits From RFID	Current State -of - the Art	Potential added value from RFID
	Cost Control		
Tracking /Loss Prevention	Increased effectiveness in preventing shrink. Tags enable	Largely Manual and less efficient	Moderate
Function	Benefits From RFID	Current State -of - the Art	Potential added value from RFID
	Efficiency		
Reverse Logistics	Unit level tagging enables better management of the returns process	Largely Manual	Moderate
Function	Benefits From RFID	Current State -of - the Art	Potential added value from RFID
	Inbound Receiving		

Store Operation	Automated receipts. Unit level tagging will increase inventory accuracy	Manual scan/data entry	Major
	Loss Prevention		
	Unit level tagging combined with smart shelves will reduce shrinkage in the retail store	Manual methods, EAS tags etc are less effective	Major
	Enhanced Check -out		
	Unit level tagging can potentially enable automatic self check out .Higher efficiency and accuracy	Manual/self check out counters less efficient	Major
	Customer Service		
	Better Management of recalls and product warranty support	Manual process	Major

	Inventory Management		
	Cycle counting and physical inventory process can be highly automated	Labor intensive manual scanning process	Major
	Exception Management		
	Enhanced visibility at a unit level enables retail store management to better handle exceptions	Manual Process	Major
Function	Benefits From RFID	Current State -of -the Art	Potential added value from RFID
	One step Receiving		
Warehouse Receiving	Automated receiving for an appointment .RFID portals will read the tags and update the inventory quantity	Receipt of Pre-labeled (barcodes) cases automatically by identification using 3D tunnel scanner	Moderate
	Automated Checks		

	Verification of discrepancies between the received merchandise and the purchase order can be automated	Automatic routing of the cases to vendor/Quality audit areas. Inspection process is manual	Moderate
	Reductions in direct labor costs		
	Manual functions like printing receiving labels, scanning/keying in the receipts a case at a time, and PO matching can be largely eliminated	Advance visibility into inbound merchandise using vendor ASN cases eliminate the need for keying-in data or PO matching	Marginal
Function	Benefits From RFID	Current State -of - the Art	Potential added value from RFID
	Simplified Put away		
Put away to reserve area in the warehouse	Pick up and drop loads without the need to scan location and case barcodes	Automatic diverts based on pre-labeled barcodes .Location and case scanning prior to stocking is	Moderate

		manual	
	Automated Updates		
	Automatic updates to reflect the quantity at the new location when a load is dropped at a reserve location	Manual scanning	Moderate
Function	Benefits From RFID	Current State -of - the Art	Potential added value from RFID
	Accurate Location Inventory		
Replenishment to pick face in the warehouse	No more case/ pallet not found type of situations	Possibility of such errors do exist	Moderate
	Simplified pick-up and drop-off		
	Pick -up and drop load without scanning the product or the location	Manual scanning	Moderate
	Automated Verification		
	Automated alerts to notify errors in stocking product	Verification though manual scan of location tag	Major
Function	Benefits From RFID	Current State -of - the Art	Potential added value from RFID

	Automated Updates		
Order filling in the warehouse	Automatically verify and update inventory quantity and pick-completion information	Manual scan /Update	Moderate
	Efficient Pallet Picks		
	Pallet pick assignments can be a more pick-up without the need for scanning	Manual scan /update	Moderate
	Efficient Case Picks		
	Task assignments for paper picks from storage locations will not need scanning	Manual scan /update	Moderate
	Automated Checks		
	Prompts alerting inaccurate pick counts	No such direct capability	Major

WAREHOUSING & INVENTORY MANAGEMENT

	(case/unit)		
Function	Benefits From RFID	Current State -of - the Art	Potential added value from RFID
	Automated dock Loading		
Warehouse Outbound Shipping	Causes and pallets can be directly conveyed from conveyors onto the trailers without scanning the outbound labels	Manual scan prior to loading case onto trailer	Major
	Automatic creation of bill of lading		
	Shipping documents will be created systemically to reflect exact trailer contents	Based on scanned data during dock loading -possibility of manual error	Marginal
	Operational Efficiency		
	Higher read accuracy and minimal diversions to 'no-read' lanes.	3D Tunnel scanners eliminate no-reads to a large extent	Marginal
Function	Benefits From	Current State -of -	Potential added value

	RFID	the Art	from RFID
	Automated Counts		
Warehouse Inventory Control	Cycle counting and physical inventory process can be highly automated	Labor intensive manual scanning process	Major

Source: Infosys Technologies Limited

RFID in Warehousing

Receiving

RFID tags might have the most potential to improve the warehouse's receiving processes. Under current bar coding practices, a worker must scan each product or case before it's moved into the warehouse. RFID technology allows significant improvements in the Throughput speed of product at the receiving dock. The RFID scanner reads the shipment within seconds as it passes through the portal readers. Additionally, the RFID technology eliminates the need to physically check the bill of lading and/or the packing slip. Furthermore, RFID will connect with the WMS system to indicate if a product needs a cross-dock movement. Cross-docking is one of the most efficient processes for moving inventory through a warehouse without storage. Cross-docking is initiated at the receiving dock. When a product is received and scanned, the WMS interfaces with the OMS to determine if this product is needed to fill an open order. If so, the product is moved literally "across the dock" to the outbound dock (or picking/packing) so the order can be completed and placed on the waiting vehicle. If the item is not needed to satisfy an open order, it is placed into storage. RFID will make this "open-order" identification faster and more reliable than traditional bar code scanners because it will occur when the product is pulled from the delivery rather than after it has been placed on the receiving dock floor. The benefits from not scanning

each shipment, automated bills of lading, and improved cross dock movements reduce labor costs and allow the receiving docks to handle a greater amount of product. For instance, if an incoming load

is needed to refill an out-of-stock item or is scheduled to depart on a cross-dock movement, the RFID system designates the load as high priority and communicates this information to the worker.²² In addition, the RFID system will help manage the flow of damaged goods into the warehouse. The damaged goods that are set aside can be read by the RFID technology as received as damaged. This process will significantly reduce labor hours spent on managing the damaged goods process.

An RFID system also offers greater efficiencies in warehouse systems that rely on conveyors.

RFID eliminates the need to ensure that cases/items are placed properly on the conveyor so that the bar code can be read accurately with the bar code reader. Normally, this means that the bar code is “face-up” or on top of the box since many bar code readers scan from above the conveyor. RFID allows for accurate reads regardless of product position, resulting in fewer reading errors. Elimination of product positioning requirements on the conveyors will also improve the speed of overall product flow through the warehouse. This will also reduce labor costs since additional workers will not be needed on the conveyor to reposition products so the bar code is facing the proper direction.

Storage

RFID technology also provides benefits in put-away accuracy and efficiency. Forklift drivers could still rely on the current WMS system to identify the locations for pallets and products. However, an RFID system can eliminate the need to scan the bar code on the pallet and at the slot location in the racks. For example, if the pallet and slot location read by the RFID scanner do not match the WMS specification, the system notifies the driver that the product has been placed in the wrong location. Moreover, the need for additional bar codes on each pallet is eliminated. This pallet identifier bar code is also called a “license plate.” Since a single scanner can identify all of the RFID tags on individual products, the placement of a license plate on the pallet level would

not be necessary. Additionally, RFID has the potential to improve temporary storage at the warehouse. Since the RFID tags can be read from anywhere, products and pallets do not have to be placed in specific or assigned locations. This is called a random location system. It is also operable with bar codes. This random system allows for a much more flexible storage environment and can help to minimize honeycombing (honeycombing is a situation that arises in a racked warehouse where large empty rack slots exist among filled slots). RFID-related applications can also be used to identify product compatibility problems. If non-compatible or hazardous products are stored near each other the RFID system could alert the employees for an immediate removal of one of the products.

Pick / Pack

RFID readers can integrate with the WMS and OMS systems to ensure that the correct items and amounts are picked. Another benefit of RFID is to help measure productivity in the warehouse. Through a type of RFID-enabled time-motion measurement, management could analyze the process to set benchmarks, evaluate employees and plan labor requirements. This is also enabled by bar code systems. The difference is that with RFID systems, manual scans of products are eliminated.

Shipping

An RFID reader can confirm that each item is placed onto the correct outbound vehicle, which can improve the accuracy of the shipping process. This verification can be made as the product moves through the portal of the outbound dock door. These processes allow for an automatic double check of the items loaded into the trailer against the bill of lading (a bill of lading must accompany each shipment tendered to a carrier; it is, among other things, a description of the shipment) or manifest (a manifest identifies the products and their locations in the outbound vehicle). It should also be noted that the use of RFID could greatly reduce the amount of employee theft in a warehouse. Placing RFID readers at exits of the facility and employee areas ensures that all items leaving the building are accounted for, regardless of the removal method.

Companies can expect savings in labor and other efficiency benefits from RFID. Table 1 summarizes where RFID cost savings lie within warehouse operations in terms of percentage savings.

Table 1: Cost savings in a distribution centre through RFID		
Task	Labour Cost	Estimated savings with Auto-ID
Receiving	5%	80-100%
Put away/replenishment	20-30%	20%
Picking	30-50%	50%
Shipping	5%	80-100%
Check-in	20-40%	80-100%
Overall		40-80%

PRACTICE AREA

Objective Type Questions

1. One of the considerations to determine the location of a warehouse should be:
 - a. Product storage
 - b. volume of the products handled
 - c. market service area and the cost of distribution from the warehouse to the market service area
 - d. type of material handling equipment

2. One of the factors affecting the number of warehouses is:
 - a. capital expenditure for material handling equipment
 - b. warehousing costs
 - c. procurement costs
 - d. packing costs

3. Cross-docking requires:
 - a. more storage space
 - b. less storage space
 - c. no storage space
 - d. none of the above

4. Maintaining stock availability for order picking is named as
 - a. Order picking
 - b. Sortation
 - c. Receiving
 - d. Replenishment

5. RDC refers to
 - a. Reliable dispatch center
 - b. Return dispatch center
 - c. Regional distribution center
 - d. Random distribution center

6. The most common measure of picking performance is
- a. Fill rate
 - b. Perfect order fulfillment
 - c. Pick rate
 - d. Binning rate
7. Which activity cost holds the major cost in warehousing activity?
- a. Receiving
 - b. Storage
 - c. Put away
 - d. Picking
8. ABC Analysis in inventory control is based on
- a. Cost of the material
 - b. Stock quantity in hand
 - c. Annual consumption value of the items
 - d. None of the above
9. Re order level system is a
- a. Independent demand system
 - b. Dependant demand system
 - c. Periodic ordering system
 - d. None of the above
10. The true multi-echelon system would reduce the cycle inventory in the whole supply chain.

True/False

11. Warehouses emphasize _____ and their primary purpose is to maximize _____.
- a. product storage; throughput
 - b. product storage; usage of available storage space
 - c. rapid movement of product; throughput
 - d. rapid movement of product; usage of available storage space

12. Throughput refers to:
- a. storage capacity of a warehousing facility
 - b. volume through a pipeline
 - c. inventory turnover in a one-month period
 - d. amount of product entering and leaving a facility in a given time period
13. Warehousing and _____ are substitutes for each other.
- a. transportation
 - b. materials handling
 - c. packaging
 - d. procurement
 - e. none of the above
14. _____ involves bringing together similar stocks from similar sources.
- a. bulk-breaking
 - b. assorting
 - c. accumulating
 - d. sorting
15. The reasons to keep inventory are:
- a. Seasonal factors of availability
 - b. Price factors
 - c. Protective buffer against delays in supply and market fluctuations for finished goods
 - d. All the above
 - e. None of the above
16. Distribution centers emphasize the rapid movement of products through a facility, and thus attempt to maximize throughput.
- True / False**
17. Warehousing is needed because patterns of production and consumption may not coincide.

True / False

18. Inventory is one of the most important sources of cost in any supply chain and it has an enormous impact on responsiveness.

True / False

19. EOQ may not applicable when the requirements are irregular, or where there is impending price rise.

True / False

20. A facility designed for cross docking should devote more space to product storage and less space to dock operations.

True / False

21. EOQ is arrived at by Balancing:

- a. Inventory holding cost and warehousing cost
- b. Cost of Storage and cost of distribution
- c. Inventory holding cost and ordering cost
- d. Inventory holding cost and total material cost

22. Using visual signals for control is a technique employed in:

- a. Kanban
- b. JIT
- c. Pull System
- d. TPM

23. Loss of product value resulting from a model or style change or technology development refers to which Inventory carrying cost is referred to as:

- a. Carrying Cost
- b. Storage
- c. Pilferage
- d. Obsolescence

24. MRP II refers to:

- a. Manufacturing Requirements Planning
- b. Materials Resources Planning
- c. Manufacturing Resource Planning
- d. Material Requirement Planning

25. _____ and Transportation are substitutes for each other.

- a. Materials handling
- b. Warehousing
- c. Packaging
- d. Procurement

26. Bringing together similar stocks from similar sources is called accumulating.

True / False

27. Bar Codes enable quick, accurate data entry.

True / False

28. Software and hardware are the most important pieces of an RFID solution.

True / False

29. _____ are advantageous for periodic and continuous transport of material between locations in warehouses and factories.

- a. Horizontal powered conveyors
- b. Gravity conveyors
- c. Fixed path conveyors
- d. None of the above

30. RFID “readers” in a read-write system are also “writers” which means information can be written to tags at any point.

True / False

Paragraph type question

1. Describe in detail the various performance metrics for material handling equipments?
2. Describe in detail the various analyses and measures to control inventory?
3. Describe in detail the 'Independent Demand System' as well as 'Dependent Demand System'?
4. Describe in detail the true multi-echelon system?
5. Explain centralized and decentralized warehousing operations.
6. What are the functions of a warehouse? Explain in detail.
7. 'Inventory management is important for a successful supply chain response'. Defend this statement.
8. Differentiate with examples single-echelon and multi-echelon networks.
9. Describe in detail the advantages and dis-advantages of a Public Warehouse and a Private Warehouse
10. Describe in detail all the functions of a Warehouse.
11. Describe in detail the main reasons/needs for holding stock as an inventory in an Enterprise
12. Compare in detail the key differences among the three approaches namely sequential, Distribution Requirements Planning and Multi-Echelon Solution for managing inventory.
13. Explain in detail the functions of Warehousing
14. What the various reasons for holding inventory in an organization
15. Explain in detail RFID
16. How is bar coding technology applied in Logistics Industry?
17. Explain the concept of Economic Order Quantity

Model Case Study**1) A Case Study – ALL WELL COMPANY**

All Well Company (AMC) manufactures two products (Alpha and Beta). AWC has 20 sales districts all over India. All products inventories are maintained locally and replenished from Mumbai every four weeks using a carrier service (Golden Transport – GT). The replenishment lead-time is one week. GT charges at the rate of Rs. $0.5 + 0.25X$ (where X is the quantity shipped in Kgs)

product	Weekly demand (mean,SD): Normally distributed	Unit weight	Unit cost
Alpha	4.5	0.1kg	Rs 300/ unit
Beta	16.5	0.05kg	Rs75 /unit

Annual inventory holding rate is 20% service level is 99.97% (corresponding to 3 sigma level). AWC is considering the following two options:

Alternative A:

Keep the current structures but start replenishing inventories every week rather than every four weeks.

Alternative B:

Eliminate inventories at sales districts, aggregate all inventories in a finished goods warehouse at Mumbai and replenish the warehouse once a week. If inventories are aggregated at Mumbai, orders will be shipped by DTDC courier service which charges at Rs7.0 + 0.70X (X = quantity shipped in kgs). An average customer order is for 1 nit of

Alpha and 10 units of Beta. Mumbai plant requires one week's lead time to replenish goods at the Mumbai warehouse.

Questions:

Advise AWC on which alternative (existing or alternative A or alternative B) is to be chosen. You may compare these alternatives based on the following criteria. Number of stocking locations, re-order level, inventory for Alpha, Beta, Annual Inventory Cost for Alpha, Beta(A), shipment weight, Annual Transportation cost (B), and Total cost (A+B).

xxxx

2) “NWDCo” Case Study

Until a few years ago, the network of NWDCo, a national wholesale distributor, comprised only DCs situated between NWDCo's suppliers and customers. Each DC would order product from the suppliers and fill orders to customers. The DCs are customer facing and have average service commitments of more than 98%. A DC typically stocks between 25,000 and 50,000 SKUs. Today, NWDCo has several RDCs and the same DCs.

Each DC is assigned to one of the RDCs. Every item that is stocked at a DC is either a *vendor-direct* or an *RDC item*. A vendor-direct item is replenished directly from an external supplier; it does not flow through any RDC. An RDC item at a DC is internally replenished from an RDC. Roughly half the company's sales are tied to items that are stocked at both the RDC and DC echelons. An RDC stocks about 10,000 SKUs.

Each RDC has its own customers that order directly from the RDC. These customers require 99% service levels. Thus, each RDC has two types of customers—external customers and internal customers represented by the DCs. Each DC orders from its RDC on a fixed schedule, but the external customers order any time they want.

The lead times from the suppliers to the RDCs are generally shorter and less erratic than the lead times from the suppliers to the DCs had been before the RDCs existed. Instead of ranging from one to three weeks, the lead times are now three to 10 days.

The time-definite deliveries between the RDCs and the DCs range from one to three days, depending on the DC.

Challenges

NWDCo's end customers have very high service requirements. One way NWDCo can assure that it meets these high service goals is to carry extra inventory at the DCs. At the RDCs, inventories are carried to replenish the DCs and to satisfy the RDCs' external customers. The problem is to deploy the optimal balance of inventory in the two echelons. NWDCo can use many control levers to shift the inventory balance between its RDCs and DCs. How should NWDCo set these to achieve service objectives

at minimum inventory? Can slow-moving products simply be centralized at the RDCs with little or no product at the DCs?

The inventory management problem is further complicated because of the high service requirements of the RDCs' external customers. The RDCs must simultaneously set aside enough inventory to satisfy external customers' demands *and* to provide the DCs with enough product on hand to satisfy the DCs' customers' demands.

An overriding question NWDCo must address is how to come up with the right demand forecasts at the RDCs. These forecasts are crucial to replenishment decisions at the RDCs.

Other challenges exist. NWDCo needs to attain and fully exploit information transparency in its network. This means the RDCs and the DCs must freely share information on demand, inventory, in-transit orders and factors that impact demand, such as promotions activity. Another problem is to synchronize the replenishment activities between the two echelons to minimize lead times and to balance orders between DCs and RDCs over the days of the week. Failure to adequately tackle

these challenges will lead to increased inventory and potential service failures because of the bullwhip effect.

Questions:

1. List out the concerns in this case.
2. Should the DC demands simply be passed up to the RDCs for use in determining statistical forecasts? Should the RDCs simply aggregate demand forecasts that are determined at the DCs?
3. Should the RDCs develop statistical forecasts based on historical shipments to the DCs? What about historical orders from the DCs?

xxx

3) Case study on Eagle Machine Company

The Eagle Machine Company has fallen on bad times. Eagle, a market of specialty restaurant equipment, has sales totaling Rs.72 million. But sales are declining while costs continue to increase. If things continue in this direction, Eagle may soon have to close its doors. At a special management meeting, the president lays it on the line! He demands that the firm break even in the remaining quarter of the year. For next year, he calls for 5 percent profits, a 20 percent increase in sales, and deeper cuts in labor, material and overhead. Later in the day, the president calls Mr.Manoharan, V.P. - Finance & Accounts, in for a discussion.

“Manoharan, I want you, Finance & Accounts people to carry the ball at the start of this game. We can’t get sales moving for six months. But you can improve your housekeeping- and Eagles profit-right away. Just think what you can do to that chart! Every penny you save is profit! So take a close look at what we buy & what we sell. I don’t care how you make your savings –by negotiations inventories, imports, anything. But put the screws on tight-right away.

“Start with inventories, they’re Sky high. So get together with manufacturing on a 10 percent cut! We have got Rs.12 million worth of materials stashed away around here, and a percent cut would save at least Rs. 300,000 a year in carrying charges. At the

same time. Get your payroll and operating expenses down 10 percent .That's in line with our company wide cut back. I know this hurts, Manoharan, because we have got some mighty fine people here in purchasing, but we cant be sentimental these days. Our over head has got to come down or we're dead!

"I' m having an executive committee meeting in one week. Have your plans ready by that time! We're betting on you, Manoharan. You have got to get us out of the hole. I know you can do it. Please interact and develop a harmonious proposal"

Mr. Manoharan starts a review along with other depts. The purchases total only Rs. 43.2 million per year. Eagle buy, a wide variety of materials, ranging from a few kgs of rare metals to sizable quantities of metal sheet. A big part of the Rupee volume is in non-ferrous castings, forgings, stampings, fasteners and sub-assemblies.

The purchasing department consists of one Sr. Manager, three buyers, and four clerks. Salaries, fringes and expenses sum to Rs.370,000 a year. The purchasing department is responsible only for buying and expediting; the manufacturing manager handles production, inventory control, receiving and traffic. Manoharan reports to the president, as do other department heads.

Manoharan learns from inventory control that raw stock inventory is Rs. 12.2 million. The marketing manager controls finished goods stocks. Manoharan wonders hoe he can deliver the cost reduction program.

Questions:

1. What actions should Manoharan take to reduce inventories by 10 percent?
2. What dangers, if any, are there in reducing inventories?
3. In what ways could the cost of goods purchased be reduced?
4. What position should Manoharan take on the president's plan to reduce the purchasing payroll by 10 percent?

-X-